	Document ID	U	Title	Current OR
1	US 20040021591 A1	☐	Processor, encoder, decoder, and electronic apparatus	341/60
2	US 20040005744 A1	☒	Crystallization apparatus, optical member for use in crystallization apparatus, crystallization method, thin film transistor, and display	438/166
3	US 20030223075 A1	☒	Compact interference measuring apparatus detecting plurality of phase difference signals	356/491
4	US 20030179209 A1	☒	Dynamic computation of chipset-supported accelerated graphics port aperture sizes	345/543
5	US 20030151002 A1	☒	Apparatus for inspecting mask	250/492.1
6	US 20030042920 A1	☒	Exposure apparatus, control method for the same, and device fabricating method	324/752
7	US 20030011747 A1	☒	Digital, high-resolution motion-picture camera	352/166
8	US 20030002739 A1	☒	Method and apparatus for using rotatable templates within look-up tables to enhance image reproduction	382/216
9	US 20030002566 A1	☒	System and method for shifting the phase of pseudorandom noise code in direct sequence spread spectrum communications	375/147
10	US 20020184480 A1	☒	Vectorized table lookup	712/300
11	US 20020181708 A1	☒	Apparatus and method for generating scrambling code in mobile communication system	380/252
12	US 20020169808 A1	☒	System and method for reordering data	708/204
13	US 20020126268 A1	☒	Projection exposure method, projection exposure apparatus, and methods of manufacturing and optically cleaning the exposure apparatus	355/67
14	US 20020090557 A1	☒	MASK AND METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE	430/5
15	US 20020057276 A1	☒	Data processing apparatus, processor and control method	345/555
16	US 20020013690 A1	☒	PACKET CLASSIFICATION STATE MACHINE HAVING REDUCED MEMORY STORAGE REQUIREMENTS	703/22
17	US 20020010878 A1	☒	Circuit configuration for generating control signals for testing high-frequency synchronous digital circuits	714/25

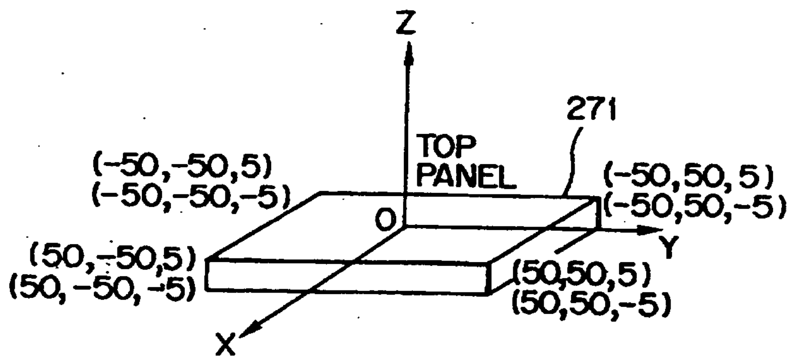


FIG. 82

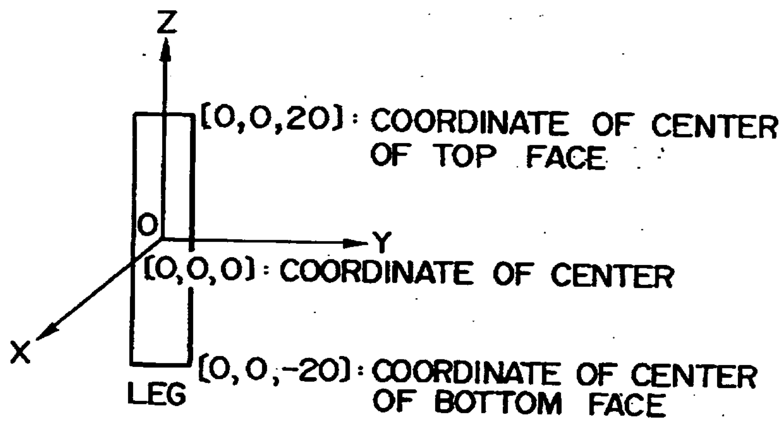


FIG. 83

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 100 & 100 & 45 & 1 \end{bmatrix}$$

WORLD TRANSFORMATION MATRIX OF TOP PANEL

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 145 & 55 & 20 & 1 \end{bmatrix}$$

WORLD TRANSFORMATION MATRIX OF LEG 272

FIG. 84

	Document ID	U	Title	Current OR
18	US 20020002671 A1	☒	Parallel processing of multiple data values within a data word	712/300
19	US 20010021477 A1	☒	Method of manufacturing a device by means of a mask phase-shififting mask for use in said method	430/5
20	US 6725298 B1	☒	Method and system for filter-processing by ensuring a memory space for a ring-buffer in digital signal processor	710/56
21	US 6718492 B1	☒	System and method for arranging bits of a data word in accordance with a mask	714/701
22	US 6715066 B1	☒	System and method for arranging bits of a data word in accordance with a mask	712/300
23	US 6687771 B2	☒	Parallel processing of multiple data values within a data word	710/62
24	US 6686591 B2	☒	Apparatus for inspecting mask	250/311
25	US 6683615 B1	☒	Doubly-virtualized texture memory	345/543
26	US 6677952 B1	☒	Texture download DMA controller synching multiple independently-running rasterizers	345/505
27	US 6657181 B1	☒	Optical element used in compact interference measuring apparatus detecting plurality of phase difference signals	250/216
28	US 6650333 B1	☒	Multi-pool texture memory management	345/552
29	US 6650317 B1	☒	Variable function programmed calculator	345/168
30	US 6629239 B1	☒	System and method for unpacking and merging bits of a data world in accordance with bits of a mask word	712/300
31	US 6629115 B1	☒	Method and apparatus for manipulating vectored data	708/209
32	US 6618804 B1	☒	System and method for rearranging bits of a data word in accordance with a mask using sorting	712/300
33	US 6587113 B1	☒	Texture caching with change of update rules at line end	345/557
34	US 6544694 B2	☒	Method of manufacturing a device by means of a mask phase-shifting mask for use in said method	430/5
35	US 6538722 B2	☒	Projection exposure method, projection exposure apparatus, and methods of manufacturing and optically cleaning the exposure apparatus	355/53
36	US 6526511 B1	☒	Apparatus and method for modifying microprocessor system at random and maintaining equivalent functionality in spite of modification, and the same microprocessor system	713/190
37	US 6446198 B1	☒	Vectorized table lookup	712/300
38	US 6440614 B1	☒	Mask and method of manufacturing semiconductor device	430/5
39	US 6438273 B1	☒	Method and apparatus for using rotatable templates within look-up tables to enhance image reproduction	382/296

TRANSFORMATION MATRIX OF PARALLEL DISPLACEMENT OF [Tx, Ty, Tz]

$$M_P = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ Tx & Ty & Tz & 1 \end{bmatrix}$$

TRANSFORMATION MATRIX OF SCALE CONVERSION OF [Sx, Sy, Sz]

$$M_S = \begin{bmatrix} Sx & 0 & 0 & 0 \\ 0 & Sy & 0 & 0 \\ 0 & 0 & Sz & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

TRANSFORMATION MATRIX OF ROTATION BY θ AROUND X AXIS

$$M_{RX} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & 0 \\ 0 & -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

TRANSFORMATION MATRIX OF ROTATION BY θ AROUND Y AXIS

$$M_{RY} = \begin{bmatrix} \cos\theta & 0 & -\sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ \sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

TRANSFORMATION MATRIX OF ROTATION BY θ AROUND Z AXIS

$$M_{RZ} = \begin{bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

FIG. 85

	Document ID	U	Title	Current OR
40	US 6437667 B1	☒	Method of tuning thin film resonator filters by removing or adding piezoelectric material	333/188
41	US 6424934 B2	☒	Packet classification state machine having reduced memory storage requirements	703/25
42	US 6411368 B1	☒	Projection exposure method, projection exposure apparatus, and methods of manufacturing and optically cleaning the exposure apparatus	355/67
43	US 6408275 B1	☒	Method of compressing and decompressing audio data using masking and shifting of audio sample bits	704/500
44	US 6396944 B1	☒	Inspection method for Levenson PSM mask	382/144
45	US 6336113 B1	☒	Data management method and data management apparatus	707/6
46	US 6263299 B1	☒	Geometric aerial image simulation	703/5
47	US H001970 H	☒	Variable function programmed system	712/32
48	US 6197456 B1	☒	Mask having an arbitrary complex transmission function	430/5
49	US 6173393 B1	☒	System for writing select non-contiguous bytes of data with single instruction having operand identifying byte mask corresponding to respective blocks of packed data	712/224
50	US 6171731 B1	☒	Hybrid aerial image simulation	430/5
51	US 6165692 A	☒	Method for manufacturing a semiconductor device and an exposure mask used therefor	430/311
52	US 6144986 A	☒	System for sorting in a multiprocessor environment	709/201
53	US 6119198 A	☒	Recursive address centrifuge for distributed memory massively parallel processing systems	711/5
54	US RE36752 E	☒	Cryptographic authentication of transmitted messages using pseudorandom numbers	380/262
55	US 6081440 A	☒	Ternary content addressable memory (CAM) having fast insertion and deletion of data values	365/49
56	US 6052769 A	☒	Method and apparatus for moving select non-contiguous bytes of packed data in a single instruction	712/3
57	US 6036350 A	☒	Method of sorting signed numbers and solving absolute differences using packed instructions	708/201
58	US 6015976 A	☒	Fabrication apparatus employing energy beam	250/492.23
59	US 6011566 A	☒	System and method to display raster images with negligible delay time and reduced memory requirements	345/600
60	US 6009203 A	☒	Method and apparatus for hybrid VLC bitstream decoding	382/233
61	US 6005503 A	☒	Method for encoding and decoding a list of variable size integers to reduce branch mispredicts	341/67
62	US 5937183 A	☒	Enhanced binary decision diagram-based functional simulation	703/14

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 45 & -45 & -25 & 1 \end{bmatrix}$$

RELATIVE TRANSFORMATION MATRIX OF LEG 272

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 45 & 45 & -25 & 1 \end{bmatrix}$$

RELATIVE TRANSFORMATION MATRIX OF LEG 273

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -45 & -45 & -25 & 1 \end{bmatrix}$$

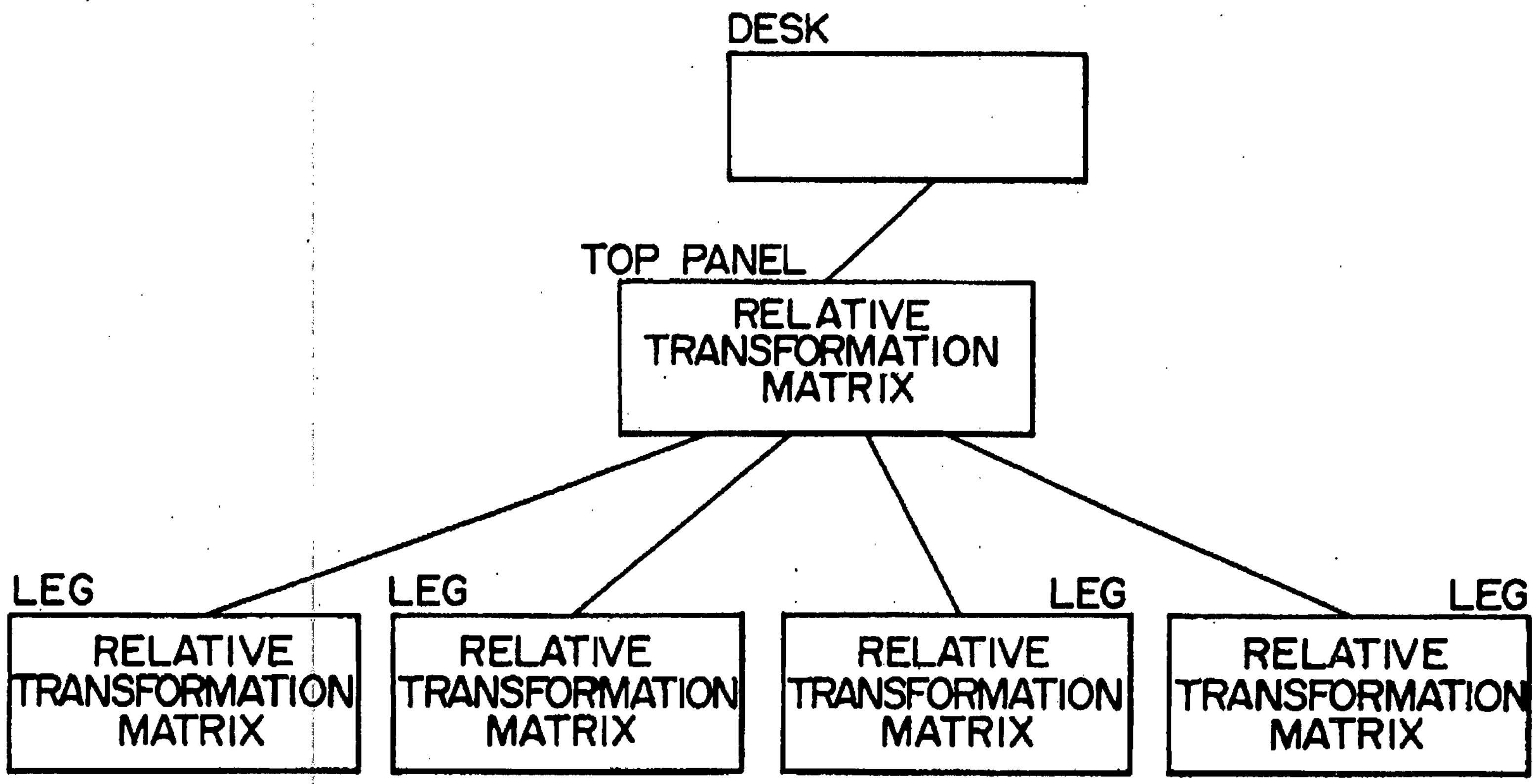
RELATIVE TRANSFORMATION MATRIX OF LEG 274

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -45 & 45 & -25 & 1 \end{bmatrix}$$

RELATIVE TRANSFORMATION MATRIX LEG OF 275

FIG. 86

	Document ID	U	Title	Current OR
63	US 5936978 A	☒	Shortened fire code error-trapping decoding method and apparatus	714/762
64	US 5920900 A	☒	Hash-based translation method and apparatus with multiple level collision resolution	711/216
65	US RE36181 E	☒	Pseudorandom number generation and crytographic authentication	713/168
66	US 5892960 A	☒	Method and computer system for processing a set of data elements on a sequential processor	712/7
67	US 5870085 A	☒	Generating text strings	345/551
68	US 5868952 A	☒	Fabrication method with energy beam	216/66
69	US 5867724 A	☒	Integrated routing and shifting circuit and method of operation	712/22
70	US 5859912 A	☒	Digital information privacy system	380/42
71	US 5841683 A	☒	Least significant bit and guard bit extractor	708/497
72	US 5841145 A	☒	Method of and system for exposing pattern on object by charged particle beam	250/492.22
73	US 5784494 A	☒	Method and apparatus for prestoring dequantization information for DCT VLC decoding	382/233
74	US 5784427 A	☒	Feedback and shift unit	377/72
75	US 5783336 A	☒	Mask for exposure	430/5
76	US 5765181 A	☒	System and method of addressing distributed memory within a massively parallel processing system	711/5
77	US 5752000 A	☒	System and method for simulating discrete functions using ordered decision arrays	703/14
78	US 5696922 A	☒	Recursive address centrifuge for distributed memory massively parallel processing systems	711/5
79	US 5696533 A	☒	Method for selecting an item on a graphics screen	345/823
80	US 5644709 A	☒	Method for detecting computer memory access errors	714/53
81	US 5627966 A	☒	Method for simulating the parallel processing of video data	714/49
82	US 5627639 A	☒	Coded aperture imaging spectrometer	356/310
83	US 5613001 A	☒	Digital signature verification technology for smart credit card and internet applications	380/254
84	US 5583985 A	☒	Graphic display processing apparatus for improving speed and efficiency of a window system	345/534
85	US 5577200 A	☒	Method and apparatus for loading and storing misaligned data on an out-of-order execution computer system	714/50


DESK
TOP PANEL
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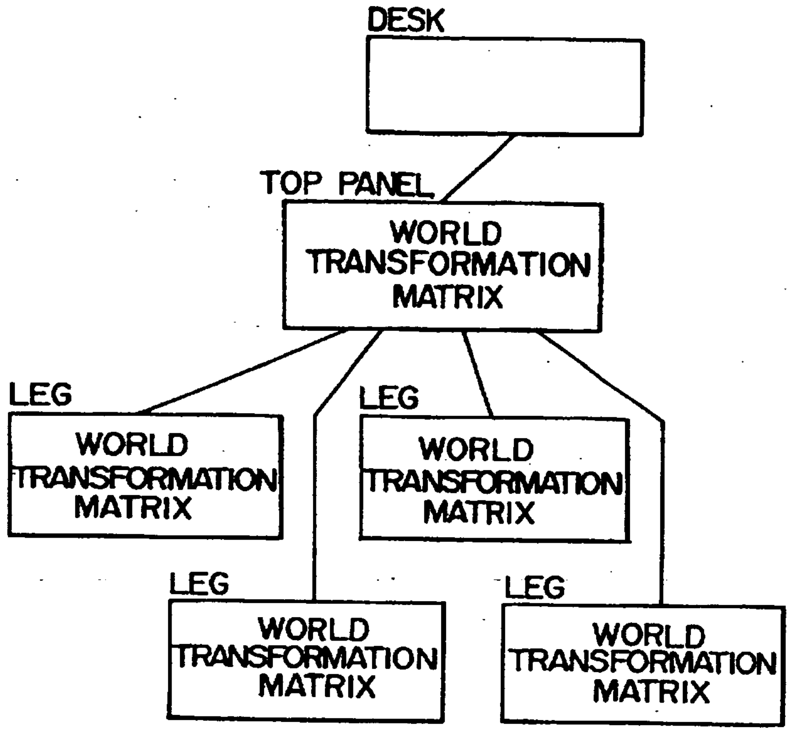
LEG
RELATIVE TRANSFORMATION MATRIX
LEG
RELATIVE TRANSFORMATION MATRIX

FIG. 87

	Document ID	U	Title	Current OR
86	US 5559722 A	☒	Process, apparatus and system for transforming signals using pseudo-SIMD processing	341/50
87	US 5555003 A	☒	Method for selecting an item on a graphics screen	345/856
88	US 5553197 A	☒	Devices for use in neural processing	706/41
89	US 5546225 A	☒	High resolution printing technique by using improved mask pattern and improved illumination system	359/559
90	US 5539663 A	☒	Process, apparatus and system for encoding and decoding video signals using temporal filtering	348/406.1
91	US 5539662 A	☒	Process, apparatus and system for transforming signals using strength-reduced transforms	358/1.15
92	US 5537338 A	☒	Process and apparatus for bitwise tracking in a byte-based computer system	709/204
93	US 5535138 A	☒	Encoding and decoding video signals using dynamically generated quantization matrices	709/204
94	US 5532940 A	☒	Process, apparatus and system for selecting quantization levels for encoding video signals	709/204
95	US 5528238 A	☒	Process, apparatus and system for decoding variable-length encoded signals	341/67
96	US 5502832 A	☒	Associative memory architecture	711/108
97	US 5497436 A	☒	System and method for bit-masked color signal scaling	382/298
98	US 5497340 A	☒	Apparatus and method for detecting an overflow when shifting N bits of data	708/552
99	US 5493514 A	☒	Process, apparatus, and system for encoding and decoding video signals	709/247
100	US 5493513 A	☒	Process, apparatus and system for encoding video signals using motion estimation	709/247
101	US 5475766 A	☒	Pattern inspection apparatus with corner rounding of reference pattern data	382/144
102	US 5430862 A	☒	Emulation of CISC instructions by RISC instructions using two pipelined stages for overlapped CISC decoding and RISC execution	703/26
103	US 5423010 A	☒	Structure and method for packing and unpacking a stream of N-bit data to and from a stream of N-bit data words	341/60
104	US 5418799 A	☒	Semiconductor laser element structure	372/44
105	US 5405490 A	☒	Flat display device and method for manufacturing the same	216/14
106	US 5398319 A	☒	Microprocessor having apparatus for dynamically controlling a kind of operation to be performed by instructions to be executed	712/226
107	US 5381425 A	☒	System for encoding and decoding of convolutionally encoded data	714/793
108	US 5377270 A	☒	Cryptographic authentication of transmitted messages using pseudorandom numbers	380/262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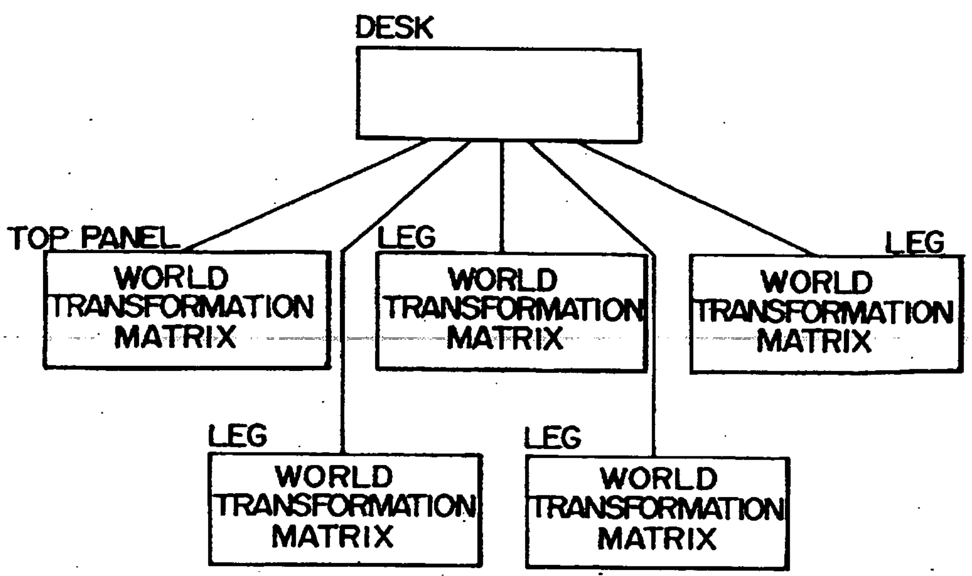
WORLD TRANSFORMATION MATRIX

FIG. 88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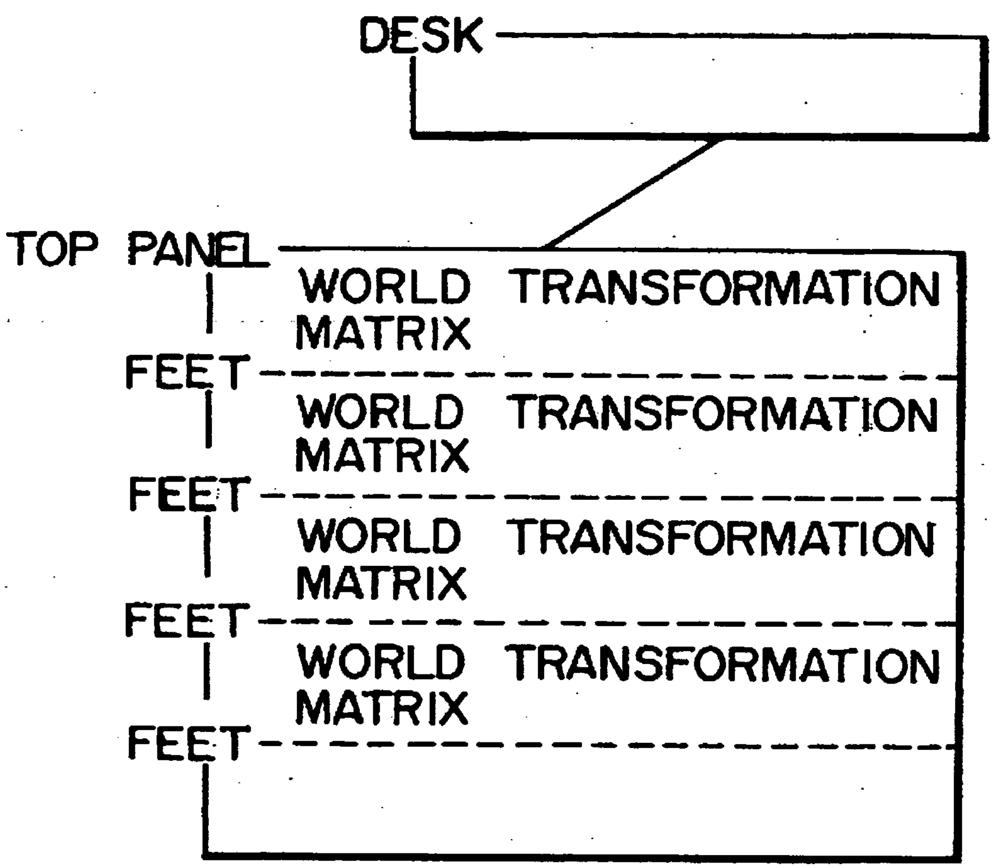
WORLD TRANSFORMATION MATRIX

FIG. 89

	Document ID	U	Title	Current OR
109	US 5363448 A	☒	Pseudorandom number generation and cryptographic authentication	713/170
110	US 5353403 A	☒	Graphic display processing apparatus and method for improving the speed and efficiency of a window system	345/563
111	US 5287452 A	☒	Bus caching computer display system	345/520
112	US 5283864 A	☒	Computer apparatus and method for graphical flip book	345/776
113	US 5267311 A	☒	Intelligent diskette for software protection	705/56
114	US 5247524 A	☒	Method for generating a checksum	714/807
115	US 5228054 A	☒	Power-of-two length pseudo-noise sequence generator with fast offset adjustment	708/252
116	US 5218647 A	☒	Method to convert between 2 color space on a 32 bit .mu.-processor	382/166
117	US 5208593 A	☒	Method and structure for decoding Huffman codes using leading ones detection	341/65
118	US 5157780 A	☒	Master-slave checking system	714/31
119	US 5128658 A	☒	Pixel data formatting	345/600
120	US 5124701 A	☒	Quantization device with variable digital coding rate	341/61
121	US 5014327 A	☒	Parallel associative memory having improved selection and decision mechanisms for recognizing and sorting relevant patterns	382/220
122	US 4992946 A	☒	Data link for gas turbine engine control	701/100
123	US 4839839 A	☒	Barrel shifter including rotate operation	708/209
124	US 4785393 A	☒	32-Bit extended function arithmetic-logic unit on a single chip	712/221
125	US 4740927 A	☒	Bit addressable multidimensional array	365/238
126	US 4653019 A	☒	High speed barrel shifter	708/209
127	US 4626674 A	☒	Focus detecting method and apparatus	250/201.8
128	US 4613748 A	☒	Focus detection apparatus employing image height correction	250/201.8
129	US 4580043 A	☒	Apparatus for detecting focus condition of imaging lens having a circular detecting array	250/201.8
130	US 4392120 A	☒	Pattern inspection system	382/199
131	US 4380046 A	☒	Massively parallel processor computer	712/22


DESK
TOP PANEL
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FEET
WORLD TRANSFORMATION MATRIX
FEET

FIG. 90

	Document ID	U	Title	Current OR
132	US 4365566 A	☒	Switch pattern selection and informational display arrangement for a multiple pattern sewing machine	112/444
133	US 4356434 A	☒	Multiple color single gun TV picture tube	315/375
134	US 4290121 A	☒	Variable function programmed calculator	365/189.07
135	US 4242675 A	☒	Display and keyboard scanning for electronic calculation or the like	345/168
136	US 4237532 A	☒	Table driven decision and control logic for digital computers	712/236
137	US 4210960 A	☒	Digital computer with overlapped operation utilizing conditional control to minimize time losses	712/230
138	US 4199811 A	☒	Microprogrammable computer utilizing concurrently operating processors	712/23
139	US 4142493 A	☒	Closed loop exhaust gas recirculation control system	123/568.21
140	US 4138719 A	☒	Automatic writing systems and methods of word processing therefor	358/1.18
141	US 4085447 A	☒	Right justified mask transfer apparatus	712/224
142	US 4074351 A	☒	Variable function programmed calculator	712/32
143	US 4045772 A	☒	Automatic focusing system	382/134
144	US 4012634 A	☒	Automatic focusing system including quantizing means	250/201.3
145	US 3946370 A	☒	Method of making light-dot distribution for the holographic storage of binary information with the aid of electronically controlled switching masks	365/125
146	US 3873974 A	☒	Scanning system for location and classification of patterns	382/134
147	US 3745533 A	☒	DIGITAL DATA STORAGE REGISTER MODULES	710/305
148	US 3745532 A	☒	MODULAR DIGITAL PROCESSING EQUIPMENT	710/316
149	US 3599160 A	☒	TIME DIVISION MULTIPLEXING	370/535
150	US 3576436 A	☒	METHOD AND APPARATUS FOR ADDING OR SUBTRACTING IN AN ASSOCIATIVE MEMORY	708/670

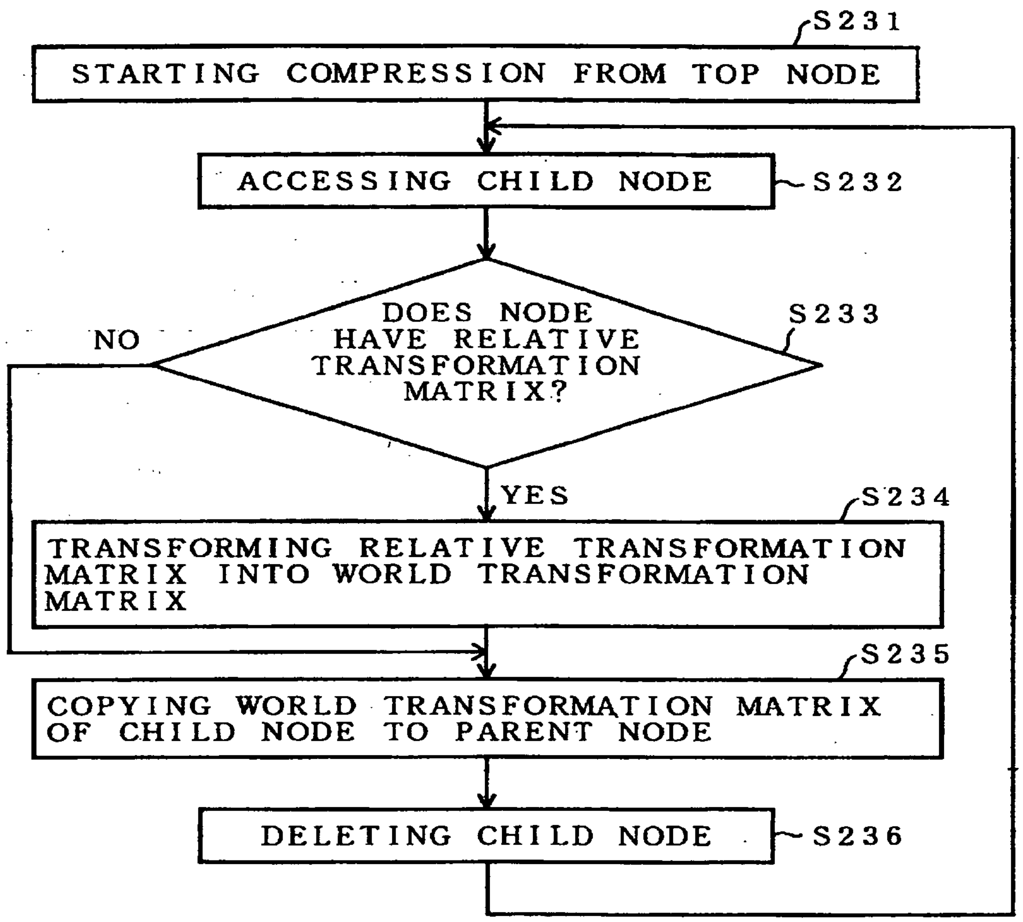
S231
STARTING COMPRESSION FROM TOP NODE
ACCESSING CHILD NODE
S232
DOES NODE HAVE RELATIVE TRANSFORMATION MATRIX?
S233
NO
YES
S234
TRANSFORMING RELATIVE TRANSFORMATION MATRIX INTO WORLD TRANSFORMATION MATRIX
S235
COPYING WORLD TRANSFORMATION MATRIX OF CHILD NODE TO PARENT NODE
DELETING CHILD NODE
S236

FIG. 91

	Document ID	U	Title	Current OR
1	US 20040073755 A1	☐	Broadcast invalidate scheme	711/144
2	US 20040054878 A1	☒	Method and apparatus for rearranging data between multiple registers	712/221
3	US 20040036829 A1	☒	Imaging unit, optical write unit, optical read unit and image forming apparatus	349/141
4	US 20040014427 A1	☒	Method and apparatus for transferring data between a source register and a destination register	455/73
5	US 20030236904 A1	☒	Priority progress multicast streaming for quality-adaptive transmission of data	709/231
6	US 20030233464 A1	☒	Priority progress streaming for quality-adaptive transmission of data	709/231
7	US 20030223397 A1	☒	Process for generating codes for CDMA communications, system and computer program product therefor	370/342
8	US 20030217119 A1	☒	Replication of remote copy data for internet protocol (IP) transmission	709/219
9	US 20030210785 A1	☒	System and method for sign mask encryption and decryption	380/210
10	US 20030200524 A1	☒	Priority coloring for VLSI designs	716/19
11	US 20030190085 A1	☒	Single-instruction multiple-data (SIMD)-based algorithms for processing video data	382/250
12	US 20030184339 A1	☒	Integrated circuit device	326/47
13	US 20030154433 A1	☒	Method and apparatus for broadcasting scan patterns in a scan-based integrated circuit	714/726
14	US 20030138098 A1	☒	Executing permutations	380/28
15	US 20030132975 A1	☒	Method and apparatus for preventing satellite induced banding by selective pixel compensation	347/5
16	US 20030129001 A1	☒	Method of manufacturing semiconductor memory device and semiconductor memory device	399/200
17	US 20030113029 A1	☒	Skim encoding method for compression of a two dimensional array of data	382/244

COMPUTER GRAPHICS DATA DISPLAY DEVICE AND METHOD BASED ON A HIGH-SPEED GENERATION OF A CHANGED IMAGE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a computer graphics device for displaying graphic data (hereinafter referred to as computer graphics data or CG data) through a computer, and more specifically to a CG data display device for generating and displaying a dot image.

2. Description of the Related Art

Recently, CG devices for generating and processing images through computer systems have been widely used in many fields of applications in industry. Among these devices, a CG dynamic image display system should present a high-speed performance to keep up with the movement of an object and should display generated images with high reality.

For example, the improvement in the CG animation technologies has increased the applications of CG simulations for easily presenting various virtual experiences. Increasing especially are "walk-through" applications of CG simulations in which a user can freely walk through a virtual world and feel as if he or she were actually experiencing a specific world.

However, with a device for realizing such CG simulations, a user often passes through a wall or feels unusual in moving around, and therefore it is impossible to feel freely moving around. Thus required is a new technology of realizing a moving in a virtual world with high reality as if it were a real world.

With the conventional CG walk-through technologies, a user walks through a three-dimensional world regardless of the position of objects around a user because the contact between a user's viewpoint and an object in a virtual world is ignored in calculation for a shift of sight.

As a result, the user passes through a wall which cannot be actually passed, or is dug in a sidewalk. Thus, the user often gets lost.

As described above, since the conventional method ignores the contact between a user's viewpoint and an object in a virtual world, the virtual movement is far from a realistic movement. Especially, it is very difficult for general people who try a CG walk-through simulation to successfully move around as they wish. Furthermore, the conventional method offers the following problems.

Apart from a contact between a viewpoint and an object, a user cannot represent using a simple system the difference in interference between two hard objects, between two soft objects, and between a hard and a soft object in a clash of two objects.

Additionally, the user cannot move around with his or her viewpoint maintaining at a constant level in a virtual world. For example, when the user goes upstairs, his or her viewpoint smoothly rises obliquely upward. However, in a virtual CG world, the user either cannot go upstairs or repeats for each step a parallel or vertical movement, resulting in an unsmooth movement (shift of sight).

Furthermore, a common user cannot easily edit the virtual world for lack of a unit for easily defining the reaction and movement of an object such that the object starts any action in response to a clash of objects or at an external instruction, and for lack of a unit for easily grasping the definition.

Recently, a CG accelerator in a workstation has made remarkable progress toward a higher speed and performance. Conspicuously realized is a CG system capable of displaying at a high speed a photo-realistic image. Thus, the time correspondence between a dynamic CG image and a real world can be successfully realized. However, the present technologies have just reached a logical time description, and have not developed a method for general purpose of representing CG images in three dimensions or four dimensions including time in a real-time mode. It is because the CG image display time depends on the complexity in form and cannot be standardized. To solve these problems and integrate the processes of multimedia, it is necessary to fix the time correspondence between a three-dimensional CG image and a real world.

Conventionally, a dynamic CG image has been generated and displayed in a sequential process on completion of the calculation for generation of an image for each frame. Therefore, the generation and display of a frame take a calculation/display time for the generation of an image. Thus, the frame interval between the display time t_{n-1} of the (n−1)th frame and the display time t_n of the n-th frame is considerably long.

In the conventional method, the change of dynamic CG images in time is described only logically, and no system is provided to keep correspondence between a displayed image and the logical description. Therefore, the logically described changes in time cannot be precisely regenerated and displayed. Practically, the time taken for a display process depends on each frame to be displayed because frames are different from one another in image complexity represented by the number of polygons, textures, etc. Furthermore, the time taken for calculation of changes of three-dimensional images also depends on the number of changing objects and the complexity in the calculation. Accordingly, the time taken for the calculation and display of a frame depends on each frame.

However, in the conventional method, frames to be displayed at given intervals in a logically described CG world have been sequentially displayed on completion of respective processes. Therefore, the time flows constantly for respective frames in the CG world, but the frames are displayed at different intervals, thereby failing in representing the actual time flow. Although the frames should be displayed at constant intervals according to the actual time flow in the CG world, the frames are actually displayed at different intervals, the time being extended or reduced in the world displayed on the screen, because the time taken for calculation or display of the frames depends on the complexity of each image. If the frames should be set such that they can be displayed at constant intervals without a deviation from actual time, they must be set at intervals of the maximum value of the time taken for the calculation and display of the frames. Thus, frames are set at undesirably long intervals and generate a problem that resultant dynamic images cannot be smoothly displayed at all.

As described above, since images are sequentially generated through necessary calculation and then displayed on completion of the calculation according to the conventional method, image frames are displayed at long intervals. Additionally, since there has been no system for keeping correspondence between the time in the world on the screen and the actual time, the time flow cannot be regenerated exactly.

Recently, computer animation is very popular in various fields of applications such as architectures, commercial

	Document ID	U	Title	Current OR
18	US 20030101430 A1	☒	PRIORITY COLORING FOR VLSI DESIGNS	716/19
19	US 20030099251 A1	☒	Method and system for buffering a data packet for transmission to a network	370/429
20	US 20030084419 A1	☒	Row-based placement scoring and legalization measure for books with phase shift mask dependencies	716/19
21	US 20030061332 A1	☒	Multiple consumer-multiple producer rings	709/223
22	US 20030055803 A1	☒	Reversing the order of a group of objects in logarithmic time	706/48
23	US 20030046423 A1	☒	Programmable system for processing a partitioned network infrastructure	709/238
24	US 20030005103 A1	☒	Cumulative status of arithmetic operations	709/223
25	US 20030001850 A1	☒	Graphic processing system having bus connection control functions	345/503
26	US 20020188821 A1	☒	Fast priority determination circuit with rotating priority	711/220
27	US 20020175961 A1	☒	Printing apparatus and printing method	347/15
28	US 20020143650 A1	☒	Ordering method and system	705/26
29	US 20020140585 A1	☒	TECHNIQUE FOR ENCODING A SEQUENCE OF PERIODIC BYTE VALUES WITH VERTICAL CORRELATION	341/60
30	US 20020138703 A1	☒	System and method for building packets	711/154
31	US 20020106567 A1	☒	Phase-shifting mask and method of forming pattern using the same	430/5
32	US 20020098639 A1	☒	Method of manufacturing semiconductor memory device and semiconductor memory device	438/238
33	US 20020060636 A1	☒	Digital-to-analog conversion circuit and image display apparatus using the same	341/150
34	US 20020056878 A1	☒	Semiconductor memory device	257/365

films, educational programs, designing skills, etc. In the computer animation, the time taken for the generation of animation can be considerably reduced by calculating and processing the movement and transformation of an enormous number of objects using a computer system. Recently, in the computer animation, physical rules have been used to display animation images to represent visually natural movement of objects.

If a long time is taken for calculation to generate animation requiring a large amount of calculation processes for a large number of objects, then visually unrealistic animation images are generated. Accordingly, even if large amount of calculation is required for a large number of objects, it is necessary to quickly perform the calculation and display so that natural and smooth animation images can be realized.

Generally, an animation generating device using computer graphics fundamentally comprises an animation data generating unit for calculating the movement and transformation of objects and an image data generating unit for generating image data (two-dimensional data) from computed geometric data of objects (three-dimensional data of a form, position, etc.). Using these units, the animation generating device repeats computing the movement and transformation of objects and generating images to produce animation images. If the animation data generating unit and the image data generating unit perform calculating and generating processes at a high speed, smooth animation images can be generated in real time.

Conventionally, a large amount of processes have been performed at a high speed in the image data generating unit through high-performance hardware (accelerator) and firmware. On the other hand, since the animation data generating unit is required to generate animation images with more realistic movements and complicated transformations out of a large amount of data, its load is undesirably large and a long time is taken for the generation of data for a single frame.

However, the conventional animation generating device needs a long time for generating data calculating the movement and transformation of the whole objects, and then generates an image.

Therefore, if it takes the animation data generating unit a longer time to calculate the movement and transformation of objects than it takes the image data generating unit to display generated images, the images are displayed at longer intervals. As a result, unsmooth and unrealistic animation images appear on a screen. Thus, a higher speed image data generating unit has not generated animation images in real time.

A flight simulator and a drive simulator are required not only to display a static image predetermined by a computer but also to display animation images, and a device like a scene simulator is required to precisely draw a real scene.

These devices display the form of an object to be displayed using a large amount of CG data. To represent a change of viewpoints and natural movements of objects appearing in an image, a large amount of CG data should be changed at very short intervals.

Conventionally, a CG data display device has performed the following process using a single central processing unit (CPU).

The CG data display device stores and updates CG data to be displayed in a data management process. Then, it reads all CG data containing those changed through an image generating process and generates images. It finally displays the images of CG data after sequentially repeating the update of the CG data and the generation of images.

The conventional CG data display device generates and displays images in an image generating process after updating data in a data management process as described above. Such CG data image generation is a time-consuming process, and images are not generated in good time when a large amount of CG data must be updated. Therefore, resultant unrealistic images should be used with a part of CG data regularly omitted. A scene simulator is also required to display minute representation of objects. Therefore, for example, a long time is taken before displaying a minute object image when a viewpoint is changed.

That is, when a large amount of CG data of dynamic images are changed at very short intervals, an image generating process cannot be completed in good time, thereby generating unrealistic animation images. Moreover, in generating static images, an operator has to kill time while the images are being generated.

As computer graphics make striking progress and are used in various fields in industry, the development of more easily operated user interfaces are earnestly demanded. One of the demanded technologies is a three-dimensional object display method of generating a three-dimensional model, editing the model (modeling), and displaying the object in three dimensions. The "displaying the object in three dimensions" indicates a display of a three-dimensional world on a screen.

In the development of a user interface, managing parts objects in a hierarchical structure and constructing data such that each data inherits the attribute of its parent effectively reduce the number of specified entries and are used in many modeling systems.

In this method, however, when a modeled three-dimensional form is displayed, inheriting the attribute of a parent requires all hierarchical tree structure to be searched, thereby consuming much time in a displaying process.

The amount of search time affects the displaying process, and depends on the depth of a hierarchy of an object data structure (that is, the number of steps of the hierarchy) and the number of objects in the object data structure.

FIG. 1 shows the configuration of the important portion of a common three-dimensional object display device for processing computer graphics. The device generates and edits a three-dimensional image, and displays it as a three-dimensional image at a certain point. The device shown in FIG. 1 comprises an object generating and editing unit 1, an editing-formatted hierarchical object data structure memory unit 2, an object displaying process unit 3, and a display device 4.

A user (that is, a designer) instructs the object generating and editing unit 1 to model data, and simultaneously instructs the object display processing unit 3 to display data. Therefore, the object generating and editing unit 1 and the object display processing unit 3 execute their processes while accessing the same data structure. During this modeling process, the internal data structure is hierarchically arranged in object units, and the data are stored in the hierarchical object data structure storing unit 2.

FIG. 2 is an example of a hierarchical object data structure. The object data are hierarchically arranged in object units (that is, for each node) as shown in FIG. 2 in the modeling process.

For example, in modeling a "room", an object is generated as a parent and root representing a room. To this parent object, connected are child objects a "chair", a "desk", and a "wall". The "room" has its attributes "color A" and "transformation matrix M1". The "desk" has its attributes "color C", "transformation matrix M3", and "form α". The

	Document ID	U	Title	Current OR
35	US 20010037561 A1	☒	Contacting-making system for two printed circuit boards	29/745
36	US 20010033626 A1	☒	System, method and computer program for decoding an encoded data stream	375/341
37	US 20010028747 A1	☒	Image processing method, apparatus and storage medium	382/239
38	US 20010028659 A1	☒	Data switching arbitration arrangements	370/413
39	US 6719397 B1	☒	Ink jet printhead identification circuit and method	347/19
40	US 6701338 B2	☒	Cumulative status of arithmetic operations	708/525
41	US 6698008 B2	☒	Row-based placement scoring and legalization measure for books with phase shift mask dependencies	716/19
42	US 6666535 B2	☒	Method and apparatus for preventing satellite induced banding by selective pixel compensation	347/5
43	US 6626517 B2	☒	Printing apparatus and printing method	347/40
44	US 6625689 B2	☒	Multiple consumer-multiple producer rings	711/110
45	US 6609245 B2	☒	Priority coloring for VLSI designs	716/21
46	US 6563440 B1	☒	Apparatus and method for decoding Huffman codes using leading one/zero string length detection	341/65
47	US 6545323 B2	☒	Semiconductor memory device including a pair of MOS transistors forming a detection circuit	257/365
48	US 6501116 B2	☒	Semiconductor memory device with MIS transistors	257/296
49	US 6499039 B1	☒	Reorganization of striped data during file system expansion in a data storage system	707/204
50	US 6459392 B1	☒	Technique for encoding a sequence of periodic byte values with vertical correlation	341/87
51	US 6421730 B1	☒	Programmable system for processing a partitioned network infrastructure	709/236
52	US 6404664 B1	☒	Twisted bit line structure and method for making same	365/69
53	US 6401117 B1	☒	Platform permitting execution of multiple network infrastructure applications	709/223
54	US 6366276 B1	☒	Touch operation signal output device	345/175
55	US 6342408 B1	☒	Method of manufacturing semiconductor memory device	438/155

"wall" has its attributes "color D", "transformation matrix M4", and "form β". The "chair" has its attributes "color B" and "transformation matrix M2". The child objects of the "chair" are "legs", a "bottom panel", and a "back panel". The "legs" has its attributes "color E" and "transformation matrix M5". The "bottom panel" has its attributes "transformation matrix M6" and "form γ". The "back panel" has its attributes "transformation matrix M7" and "form δ". Furthermore, the "legs" has four child objects "foot", each having its own attribute "form ε", "form ζ", "form η", or "form κ" and are arranged hierarchically. Each object can be assigned an attribute indicating texture instead of color, if required.

If a "foot" is composed of two parts, then it is a parent object to the two parts having attitudes of respective forms. In this case, a modeling operation can be performed without specifying their foot color or transformation matrix because the child objects inherit the attributes of their parent objects.

If the color of the entire legs or the texture of the chair should be changed, only the color attribute E or the texture attribute of the chair object has to be changed to simultaneously change the entire legs including four respective feet because each foot inherits the attributes of its parent objects legs. Inheriting attributes enables a user interface to be provided and modeled without redundant entries specified by a user.

When data are displayed on the display device 4, the object display processing unit 3 searches for and displays each object in a hierarchical object data structure while taking the attributes of the parent object into consideration.

However, to make such a hierarchical modeling data structure more effective, it is necessary to divide the parts into separate groups or have the attributes inherited more frequently. Necessarily increased are the number of objects and the depth of hierarchy. Furthermore, an enormous number of displaying operations should be performed to allow a user to issue a display instruction without considering the number of objects and the depth of the hierarchical structure.

As shown in FIG. 1, since both the object generating/editing process 1 and the object displaying process unit 3 access the object data in the hierarchical object data structure memory unit 2 in performing a modeling process and a displaying process, the hierarchical object data structure which is effectively used in a modeling operation is used as is in a display process. Therefore, with the increasing number of objects, an enormous number of object searching processes are carried out, thereby taking much process time to display data.

SUMMARY OF THE INVENTION

An important object of the present invention is to provide a CG data display device for displaying realistic and lifelike dynamic image, and is explained in detail as listed below.

First, simplified is an editing process in which a virtual CG world is defined so that a simulation of realistic and lifelike movements and changes of states can be easily realized at a high speed through a smaller amount of calculation processes.

Second, data are displayed at short frame intervals with display time and actual time corresponding to each other without affecting a real time displaying process of dynamic CG images.

Third, a smooth and realistic animation is realized by an increased number of display times at shorter image display intervals and at a high speed display.

Fourth, images are generated at a high speed when CG data are updated so that data can be displayed realistically.

Fifth, a display process is performed at a high speed by decreasing the time taken for an object searching process associated with the display.

The present invention relates to the CG data display device and method for displaying CG data. The CG data display device according to the present invention comprises a management unit for managing CG data, and a generating unit for generating image data from the CG data output by the management unit and displaying the generated data. The image data are generated by the generating unit and displayed as static or dynamic images on a screen.

The attributes of an object managed by the management unit includes an interference attribute indicating a movement generated through an interference by a contact, clash, etc. with another object, and another reaction attribute indicating a reaction generated by an interference.

The management unit stores a hierarchical object data structure in an editing form, controls the number of objects simultaneously calculated, and calculates the form, position, etc. of an object so that CG data can be updated. At this time, the change in state of an object is calculated according to the attributes indicating the interference or the reaction between objects to be displayed. Then, output are the CG data obtained by calculation, or are change data minimal for the update of the CG data.

The management unit predicts the time taken for the calculation of data in the management unit and for the generation of image data in the generating unit to control the time relating to the data calculation and the image data generation.

The generating unit stores the hierarchical object data structure in an editing form, generates image data and outputs them to a display unit upon receipt of updated CG data from the management unit. If the generating unit receives from the management unit the change data for use in updating the CG data, it updates the CG data according to the change data and generates image data.

Since the management unit and the generating unit are independent of each other, the management unit performs a calculation process on a frame, and the generating unit concurrently performs a displaying process on another frame in a pipeline system, thereby speeding up the entire process.

Introducing an interference attribute and a reaction attribute diversifies the movement of an object in a virtual world and realizes a realistic shift of a viewpoint. Furthermore, the calculation is simplified and the time taken for a calculation process can be considerably reduced.

The management unit predicts a display time of a corresponding frame from the time taken for a calculation process and a displaying process, and obtains through calculation the CG data at the predicted display time. Upon completion of the calculation process, the display time of the frame is reestimated. Then, it is determined whether or not it can be displayed at the initially predicted time.

If a reestimated display time is earlier than the predicted time, then the generating unit extends the display of the frame and displays it at the predicted time. If the reestimated display time is much later than the predicted time, then the frame is not displayed.

Through the time control as described above, each frame of dynamic images can be displayed at a time corresponding to the actual time for the frame without affecting the realistic representation in the virtual world.

	Document ID	U	Title	Current OR
56	US 6326695 B1	☒	Twisted bit line structures and method for making same	257/776
57	US 6304626 B1	☒	Two-dimensional array type of X-ray detector and computerized tomography apparatus	378/19
58	US 6292018 B1	☒	Configurable cellular array	326/41
59	US 6280888 B1	☒	Phase-shifting mask with multiple phase-shift regions	430/5
60	US 6263353 B1	☒	Method and apparatus for converting between different digital data representation formats	708/204
61	US 6255848 B1	☒	Method and structure for reading, modifying and writing selected configuration memory cells of an FPGA	326/41
62	US 6252608 B1	☒	Method and system for improving shadowing in a graphics rendering system	345/473
63	US 6182253 B1	☒	Method and system for automatic synchronous memory identification	714/718
64	US 6176862 B1	☒	Hair-removing device with rotary roller equipped with pain-soothing device	606/133
65	US 6169241 B1	☒	Sound source with free compression and expansion of voice independently of pitch	84/605
66	US 6157955 A	☒	Packet processing system including a policy engine having a classification unit	709/228
67	US 6154809 A	☒	Mathematical morphology processing method	711/108
68	US 6130461 A	☒	Semiconductor memory device	257/369
69	US 6114095 A	☒	Method of manufacturing electronic device using phase-shifting mask with multiple phase-shift regions	430/311
70	US 6108101 A	☒	Technique for printing with different printer heads	358/1.9
71	US 6101276 A	☒	Method and apparatus for performing two pass quality video compression through pipelining and buffer management	382/236
72	US 6066180 A	☒	Automatic generation of phase shift masks using net coloring	716/19
73	US 6014187 A	☒	Display device	349/15
74	US 5995080 A	☒	Method and apparatus for interleaving and de-interleaving YUV pixel data	345/603
75	US 5991249 A	☒	Optical track sensing device	369/44.42
76	US 5983291 A	☒	System for storing each of streams of data bits corresponding from a separator thereby allowing an input port accommodating plurality of data frame sub-functions concurrently	710/52
77	US 5966138 A	☒	Image processing method and apparatus for rotating an image in an area of an original	345/658
78	US 5941937 A	☒	Layout structure for barrel shifter with decode circuit	708/209

The management unit does not simultaneously calculate the movements of all objects in a screen, but calculates them separately and transmits the results to the generating unit. Each time the generating unit receives a calculation result, it converts the result into image data for display. Thus, the image data are displayed at short intervals, thereby displaying smooth dynamic images.

If the minimal CG data indicating the type of change are transmitted from the management unit to the generating unit as change data, then the transmission cost can be considerably reduced.

The generating unit stores tree-structured object data in a compressed format in which data are stored in a smaller number of layers and as smaller number of objects than those stored in the management unit, thereby shortening the search time for display. Thus, an attribute-inheritable object can be effectively edited and a displaying process can be performed at a high speed.

According to the CG data display device and method of the present invention, image data are updated and displayed at a high speed to generate precise and realistic dynamic images.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the configuration of the important portion of a common three-dimensional object display device;

FIG. 2 shows an example of a hierarchical object data structure;

FIG. 3 shows the configuration of the computer graphics data display device according to the embodiment of the present invention;

FIG. 4 is the block diagram showing the configuration of the first embodiment;

FIG. 5 shows an example of a virtual world illustrating the first embodiment of the present invention;

FIG. 6 shows an example of the object information about a steps forming part of the virtual world;

FIG. 7 shows an example of the object information about a handrail forming part of the virtual world;

FIG. 8 shows an example of the object information about a window forming part of the virtual world;

FIG. 9 shows an example of the object information about a floor forming part of the virtual world;

FIG. 10 shows an example of the object information about a door forming part of the virtual world;

FIG. 11 shows an example of the object information about a door knob forming part of the virtual world;

FIG. 12 shows an example of the object information about a box forming part of the virtual world;

FIG. 13 shows an example of the object information about a viewpoint forming part of the virtual world;

FIG. 14 shows the structure of the attribute setting menu according to the first embodiment of the present invention;

FIG. 15 shows an example of a display of the interference attribute according to the first embodiment of the present invention;

FIG. 16 shows an example of a display of the attribute of the steps according to the first embodiment of the present invention;

FIG. 17 shows an example of a display of the reaction attribute according to the first embodiment of the present invention;

FIG. 18A shows an example of a setting screen of the reaction attribute of the contact switch according to the first embodiment of the present invention;

FIG. 18B shows an example of a setting screen of the reaction attribute of the rotating object according to the first embodiment of the present invention;

FIG. 18C shows an example of a setting screen of the reaction attribute of the sound generating object according to the first embodiment of the present invention;

FIG. 19 is the process flowchart according to the first embodiment of the present invention;

FIG. 20 is the flowchart showing the movement interference calculation process between an object and a wall;

FIG. 21 is the flowchart showing the movement interference calculation process between the object and the steps;

FIG. 22 shows an example of the amendment to the position of the object interfering with the steps;

FIG. 23 is the flowchart showing the movement interference calculation process between the object and the floor;

FIG. 24 shows an example of the amendment to the position of the object interfering with the floor;

FIG. 25 is the flowchart showing the movement interference calculation process between the object and a sliding door;

FIG. 26 shows the configuration according to the second embodiment of the present invention;

FIG. 27 shows the time relationship between the calculation process and the display process according to the second embodiment;

FIG. 28 shows an example of a process performed when a prediction error generates the inversion of time in the second embodiment;

FIGS. 29 and 30 are the process flowchart of the time control unit;

FIGS. 31 is the process flowchart of the predicting unit;

FIG. 32 is the process flowchart of the calculating unit;

FIG. 33 is the process flowchart of the display unit;

FIG. 34 shows the changing object management unit;

FIG. 35 shows an example of the configuration of the system according to the second embodiment;

FIG. 36 shows the configuration of the important portion according to the third embodiment of the present invention;

FIG. 37 is the process flowchart of the device according to the third embodiment;

FIG. 38 shows the data structure of the animation data storage unit shown in FIG. 36;

FIG. 39 shows the contents of each object;

FIG. 40 shows the animation data;

FIG. 41 is the correspondence list of the animation method and the data;

FIG. 42 shows an example of the internal configuration of the animation data generating unit shown in FIG. 36;

FIG. 43 shows the internal configuration of the update control unit shown in FIG. 36;

FIG. 44 is the flowchart of the process performed by the animation data generating unit;

FIG. 45 is the flowchart of the process performed by the update control unit;

FIG. 46 shows an example of the internal configuration of the animation data generating unit for weighting the animation method;

FIG. 47 is the flowchart of the process performed by the data acquiring unit;

FIG. 48 shows an example of the internal configuration of the animation data generating unit for weighting the number of polygon;

	Document ID	U	Title	Current OR
79	US 5927871 A	☒	Printer having scroll print buffer and printing method	400/61
80	US 5895956 A	☒	Semiconductor memory device	257/350
81	US 5883813 A	☒	Automatic generation of phase shift masks using net coloring	716/19
82	US 5875200 A	☒	Reed-Solomon code system employing k-bit serial techniques for encoding and burst error trapping	714/784
83	US 5870097 A	☒	Method and system for improving shadowing in a graphics rendering system	345/426
84	US 5867690 A	☒	Apparatus for converting data between different endian formats and system and method employing same	710/65
85	US 5864375 A	☒	Display device	349/15
86	US 5861761 A	☒	Hierarchically connectable configurable cellular array	326/41
87	US 5854760 A	☒	Two-dimensional PE array, content addressable memory, data transfer method and mathematical morphology processing method	365/49
88	US 5844825 A	☒	Bidirectional shifter circuit	708/209
89	US 5835496 A	☒	Method and apparatus for data alignment	370/514
90	US 5831448 A	☒	Function unit for fine-gained FPGA	326/41
91	US 5812472 A	☒	Nested loop method of identifying synchronous memories	365/201
92	US 5798656 A	☒	Match register with duplicate decoders	326/39
93	US 5786112 A	☒	Photomask manufacturing process and semiconductor integrated circuit device manufacturing process using the photomask	430/5
94	US 5777722 A	☒	Scanning exposure apparatus and method	355/53
95	US 5764938 A	☒	Resynchronization of a superscalar processor	712/200
96	US 5754805 A	☒	Instruction in a data processing system utilizing extension bits and method therefor	712/200
97	US 5731853 A	☒	Display device	349/15
98	US 5720021 A	☒	Image processing apparatus for storing image data to a page memory	345/581
99	US 5717440 A	☒	Graphic processing having apparatus for outputting FIFO vacant information	345/558
100	US 5680340 A	☒	Low order first bit serial finite field multiplier	708/492
101	US 5670897 A	☒	High speed mask register for a configurable cellular array	326/41

FIG. 49 shows an example of the internal configuration of the animation data generating unit comprising a moving object list generating unit;

FIG. 50 is the flowchart of the process performed by the moving object list generating unit;

FIG. 51 shows an example of the moving object list;

FIG. 52 shows an example of the configuration of another configuration of the important portion of the third embodiment;

FIG. 53 is the block diagram according to the fourth embodiment of the present invention;

FIG. 54 shows the configuration of the system according to the fourth embodiment;

FIG. 55 shows the configuration of the CG data management unit;

FIG. 56 shows the configuration of the CG data image generating unit;

FIG. 57 is the flowchart of the operation of the first processing unit;

FIG. 58 is the detailed flowchart of the CG data management process;

FIG. 59 is the detailed flowchart of the CG calculation process;

FIG. 60 is the flowchart of the operation of the second processing unit;

FIG. 61 is the detailed flowchart of the CG data image generating process;

FIG. 62 shows the time relationship between the process performed by the first processing unit and that performed by the second processing unit;

FIG. 63 shows the configuration of the flight simulator according to the fourth embodiment;

FIG. 64 shows the configuration of the test course simulator according to the fourth embodiment;

FIG. 65 shows the configuration of the scene simulator according to the fourth embodiment;

FIG. 66A shows an example of the display screen of the drive simulator according to the fourth embodiment;

FIG. 66B shows an example of the changed display screen of the drive simulator according to the fourth embodiment;

FIG. 67 shows the data structure according to the structure of the C language;

FIG. 68 is the flowchart of the data retrieval process;

FIG. 69 shows the shift of the viewpoint;

FIG. 70 shows an example of the configuration of the CG data;

FIG. 71 shows the configuration of another system according to the fourth embodiment;

FIG. 72 shows the fourth embodiment realized by the multiprocess capabilities;

FIG. 73 shows the configuration of the important portion according to the fifth embodiment;

FIG. 74A shows an example of a hierarchical object data structure composed of three objects;

FIG. 74B shows an example of a hierarchical object data structure compressed by ignoring the inheritance of objects;

FIG. 75 shows an example of a hierarchical object data structure compressed according to color attributes according to the fifth embodiment;

FIG. 76A shows an example of the hierarchical object data structure inheriting a transformation matrix;

FIG. 76B shows an example of a hierarchical object data structure compressed according to transformation matrix attributes according to the fifth embodiment;

FIG. 77A shows an example of the hierarchical object data structure inheriting a relative transformation matrix;

FIGS. 77B shows an example of a hierarchical object data structure compressed according to relative transformation matrix attributes according to the fifth embodiment;

FIG. 78 shows the contents of each node of the tree structure;

FIG. 79 is the flowchart of the process performed by the object data structure compressing unit shown in FIG. 73;

FIG. 80 shows an example of a pointer to a child node;

FIG. 81 shows a desk in the world coordinate system;

FIG. 82 shows the modeling coordinate system of the top panel;

FIG. 83 shows the modeling coordinate system of the foot;

FIG. 84 shows the world transformation matrix of the top panel and the world transformation matrix of the foot;

FIG. 85 shows the transformation matrix in the three-dimensional graphics;

FIG. 86 shows the relative transformation matrix of the foot;

FIG. 87 shows the hierarchical object data structure having a relative transformation matrix as an attribute;

FIG. 88 shows an example of the hierarchical object data structure having an attribute of a world transformation matrix;

FIG. 89 shows another example of the hierarchical object data structure having an attribute of a world transformation matrix;

FIG. 90 shows the compressed hierarchical object data structure having a world transformation matrix as an attribute; and

FIG. 91 is the flowchart of the compressing process of the hierarchical object data structure having matrix information as an attribute.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention are explained below by referring to the attached drawings.

FIG. 3 shows a configuration of the CG data display device according to the embodiment of the present invention. The CG data display device shown in FIG. 3 comprises a management unit 11 for receiving CG data and performing calculation according to the information input externally and a generating unit 21 for generating image data from the CG data output by the management unit 11 and transmitting them to a display unit not shown in FIG. 3.

The display unit displays on a screen the image data received from the generating unit 21.

The management unit 11 comprises an object information memory unit 12, a state change calculating unit 13, a predicting unit 14, a time control unit 15, an animation data generating unit 16, an update control unit 17, a first processing unit 18, and an editing-format hierarchical object data structure memory unit 19.

The generating unit 21 comprises an image data generating unit 22, a second processing 23, and a display-format hierarchical object data structure memory unit 24.

The object information memory unit 12 stores attributes indicating interference and reaction between objects to be displayed. The state change calculating unit 13 calculates a state change of objects according to the attributes of the objects stored in the object information memory unit 12.

	Document ID	U	Title	Current OR
102	US 5668941 A	☒	Optimum implementation of X-Y clipping on pixel boundary	345/626
103	US 5662785 A	☒	Method for masking a workpiece and a vacuum treatment facility	204/298.25
104	US 5659557 A	☒	Reed-Solomon code system employing k-bit serial techniques for encoding and burst error trapping	714/752
105	US 5649225 A	☒	Resynchronization of a superscalar processor	712/23
106	US 5611064 A	☒	Virtual memory system	711/209
107	US 5602986 A	☒	Data processing and memory systems with retained background color information	345/502
108	US 5586256 A	☒	Computer system using multidimensional addressing between multiple processors having independently addressable internal memory for efficient reordering and redistribution of data arrays between the processors	710/100
109	US 5552722 A	☒	Mask registor for a configurable cellular array	326/41
110	US 5546532 A	☒	Data-array processing system	345/556
111	US 5539898 A	☒	Data-array processing system wherein parallel processors access to the memory system is optimized	711/167
112	US 5528176 A	☒	Register with duplicate decoders for configurable cellular array	326/105
113	US 5526296 A	☒	Bit field operating system and method with two barrel shifters for high speed operations	708/209
114	US 5519829 A	☒	Data-array processing and memory systems	345/530
115	US 5500609 A	☒	Wildcard addressing structure for configurable cellular array	326/41
116	US 5497395 A	☒	Method and apparatus for modulating signal waveforms in a CDMA communication system	370/209
117	US 5471628 A	☒	Multi-function permutation switch for rotating and manipulating an order of bits of an input data byte in either cyclic or non-cyclic mode	712/223
118	US 5469547 A	☒	Asynchronous bus interface for generating individual handshake signal for each data transfer based on associated propagation delay within a transaction	713/600
119	US 5469003 A	☒	Hierarchically connectable configurable cellular array	326/39
120	US 5450313 A	☒	Generating local addresses and communication sets for data-parallel programs	717/151
121	US 5448075 A	☒	Electron-beam exposure system having an improved rate of exposure throughput	250/492.22
122	US 5440426 A	☒	Optical spatial filtering for attenuating the zero diffractive orders of mutually incoherent light beams	359/559
123	US 5414701 A	☒	Method and data structure for performing address compression in an asynchronous transfer mode (ATM) system	370/395.3

The predicting unit 14 predicts time taken for data calculation in management unit 11 and time taken for generation of image data in the generating unit 21. The time control unit 15 performs time control on the data calculation and the image data generation according to the prediction by the predicting unit 14.

The animation data generating unit 16 calculates a form and a position of an object to update CG data. The update control unit 17 controls the number of objects generated at one time by the animation data generating unit 16.

The first processing unit 18 manages CG data. When the CG data are subject to a change, the CG data associated with the change are output as change data. The second processing unit 23 stores the CG data, and upon receipt of the change data, it updates the CG data based on the change data, and generates image data.

The editing-format hierarchical object data structure memory unit 19 stores a hierarchical object data structure in an editorial form. The display-format hierarchical object data structure memory unit 24 stores the hierarchical object data structure in a display form.

The object information memory unit 12 and the state change calculating unit 13 are explained in association with the first embodiment of the present invention. The predicting unit 14 and the time control unit 15 are explained in association with the second embodiment. In association with the third embodiment, the animation data generating unit 16 and the update control unit 17 are explained. In association with the fourth embodiment, the first processing unit 18 and the second processing unit 23 are explained. Furthermore in association with the fifth embodiment, explained are the editing-format hierarchical object data structure memory unit 19 and the display-format hierarchical object data structure memory unit 24.

FIG. 4 is a block diagram showing an example of a configuration according to the first embodiment of the present invention.

In FIG. 4, an input device 31 refers to a key board, a pointing device, etc. A processing device 32 comprises a CPU, a memory, etc. An attribute defining/setting unit 33 defines and sets an attribute designating a condition of a state change of an object in a virtual world. A viewpoint volume defining unit 34 defines a volume of a viewpoint in the virtual world. An activate instruction input unit 35 receives an instruction for activating an object from the input device 31.

The object information memory unit 12 stores form data of an object, position information and other physical information for each object in the virtual world. According to the first embodiment, the object information memory unit 12 comprises an attribute memory unit 36 for storing an interference attribute or a reaction attribute of an object.

The state change calculating unit 13 calculates a state change of an object according to the attribute of an associated object stored in an attribute memory unit 36 as a reaction of the movement of the object in the virtual world or in response to an external activate instruction. An attribute distribution display unit 37 displays the attribute information of each object stored in the attribute memory unit 36. A result display unit 38 displays a result of the calculation performed by the state change calculating unit 13. A sound output unit 39 outputs a sound or a voice when a sound output is defined as a reaction attribute of an object.

A display device 40 is a graphic display device for displaying the virtual world. A sound output device 41 is an output device comprising a speech synthesizing device or a speaker.

The attribute defining/setting unit 33 defines an attribute relating to the interference or reaction between the objects in the virtual world and sends the definition to the attribute memory unit 36. The state change calculating unit 13 calculates a position of movement of an object for each time step, and obtains an interference result through an attribute of the object stored in the attribute memory unit 36 if the object interferes with another object. The result display unit 38 displays a result calculated by the state change calculating unit 13 on the display device 40.

An interference attribute and a reaction attribute are typical attributes set by the attribute defining/setting unit 33. The interference attribute indicates the interaction between a first object in the virtual world and a second object in contact with the first object. A state change calculating unit 13 calculates the movement of an object movable in each time step. If it is determined that an object has moved and come in contact with another object (interference), the state change calculating unit 13 refers to the interference attribute set in the attribute memory unit 36 and calculates a result after the interference.

If a first object interferes with a second object, then the attribute defining/setting unit 33 defines an interference attribute indicating the restrictions as the constraint condition on the movement of the second object. For example, if an attribute of a "wall" is defined, then another object (including a user's viewpoint) that may interfere the wall can be included in a movement interference calculation such that the interfering object cannot pass through an object assigned the wall attribute.

Upon receipt of an input from the input device 31, the viewpoint volume defining unit 34 defines a size and a form of a volume of a viewpoint around the user's viewpoint. The viewpoint volume is regarded as space surrounding the position of user's eyes, and processed in a movement interference calculation. The state change calculating unit 13 allows the user's viewpoint to move around at a constant height in a virtual world by calculating the movement of the viewpoint based on the correlation between the viewpoint volume and the attribute of another object.

The attribute defining/setting unit 33 defines and sets an attribute indicating an average slope angle which is a constraint condition set when a viewpoint or a specific object passes over an object having an interference restriction attribute of, for example, steps. If the attribute is defined, the state change calculating unit 13 calculates based on the average slope angle the movement of the viewpoint or the specific object moving over the object assigned the attribute.

The attribute defining/setting unit 33 also defines and sets an attribute, using a restriction at the time of an interference as a contact force parameter function, indicating restriction information depending on the contact force generated by an interference. The state change calculating unit 13 calculates not only the existence of an interference but also the contact force generated by the interference so that an attribute of, for example, a paper partition, which indicates no influence if a small contact force is given but is broken by a large contact force, can be realized.

Furthermore, the attribute defining/setting unit 33 defines and sets as a reaction attribute a reaction movement of an object having an interference as an activation switch. The reaction attribute determines the moment or the method of a state change of an object in a movement interference calculation on the object performed by the state change calculating unit 13.

	Document ID	U	Title	Current OR
124	US 5408632 A	☒	Semiconductor memory having a bit position decoder and date re-ordering circuitry for arranging bits in a word of data	365/230.06
125	US 5340992 A	☒	Apparatus and method of detecting positional relationship using a weighted coefficient	250/548
126	US 5280488 A	☒	Reed-Solomon code system employing k-bit serial techniques for encoding and burst error trapping	714/784
127	US 5276800 A	☒	Image writing control unit having memory area for image	345/561
128	US 5276691 A	☒	Method for the control of receiver synchronization in a mobile phone	714/798
129	US 5247688 A	☒	Character recognition sorting apparatus having comparators for simultaneous comparison of data and corresponding key against respective multistage shift arrays	707/7
130	US 5218562 A	☒	Hamming data correlator having selectable word-length	708/422
131	US 5218431 A	☒	Raster image lossless compression and decompression with dynamic color lookup and two dimensional area encoding	348/472
132	US 5112149 A	☒	Velocity responsive head driving control apparatus of manual sweeping printer	400/88
133	US 5103749 A	☒	Process and sewing machine for sewing together layers of fabric according to a pattern	112/475.03
134	US 5095523 A	☒	Signal processor including programmable logic unit formed of individually controllable output bit producing sections	712/42
135	US 5095446 A	☒	Circuit for and method of controlling output buffer memory	345/571
136	US 5091874 A	☒	Encoder apparatus	708/211
137	US 5073864 A	☒	Parallel string processor and method for a minicomputer	708/212
138	US 5046023 A	☒	Graphic processing system having bus connection control capable of high-speed parallel drawing processing in a frame buffer and a system memory	345/619
139	US 4999808 A	☒	Dual byte order data processor	712/300
140	US 4896133 A	☒	Parallel string processor and method for a minicomputer	340/146.2
141	US 4843236 A	☒	Movable object position detecting method and apparatus	250/231.1
142	US 4802116 A	☒	Programmed controller	703/23
143	US 4608706 A	☒	High-speed programmable timing generator	377/39
144	US 4442527 A	☒	Synchronization systems	375/134
145	US 4389706 A	☒	Digital computer monitored and/or operated system or process which is structured for operation with an improved automatic programming process and system	700/1
146	US 4326190 A	☒	Boundary trace slope feature detection system	382/197

The attribute defining/setting unit 33 also defines and sets a reaction attribute indicating a state change of an object at an instruction from the input device 31 so as to enable a reaction attribute defined and set for the object to be activated on an occasion other than an interference. At an activate instruction from the activate instruction input unit 35, the state change calculating unit 13 checks the reaction attribute of the object, and changes the state of the object in accordance with the reaction attribute.

Furthermore, the attribute defining/setting unit 33 defines and sets as one of reaction attributes a sound output attribute indicating an output of a specified sound or voice. When an object having a sound output attribute comes in contact with another object, or when an activate instruction is issued to the object having the sound output attribute, the sound output unit 39 outputs a specified sound or voice through the sound output device 41.

The attribute distribution display unit 37 refers to the attribute memory unit 36 and displays the information about the attribute defined and set for an object in the virtual world with the object in the virtual world.

The present invention can speed up a movement interference calculation of an object and realize the feeling of a realistic movement in a virtual world by introducing the concept of an interference attribute and a reaction attribute to an object in a virtual world. That is, post-interference states of objects can be easily calculated and realized by referring to, for example, a predetermined interference attribute. Therefore, a viewpoint or a moving object can be prevented from being buried in a wall or other objects. Furthermore, the movement of a user's viewpoint can be realistically realized in a walk-through simulation, and a common user not familiar with CG can smoothly move in the virtual world.

According to the present invention, a restriction can be defined and set on an object as an interference attribute when objects interferes with each other in a virtual world. For example, if an object is assigned an attribute of a "wall" and if it is also defined that a user's viewpoint, that is, an interfering object, cannot pass through the object assigned the attribute of a wall, then the user's viewpoint determines a contact with the wall at a walk-through simulation. The viewpoint does not pass into the wall when it comes in contact with the wall, but it moves along the wall, thereby solving the problem that the viewpoint passes through the wall and gets lost.

Especially, the viewpoint volume defining unit 34 defines the size, form, etc. for a user's viewpoint volume and performs an interference calculation using size, form, etc. of the viewpoint so that the user can walk around at a constant height or a user's height on an object having an attribute of a "floor" as an interference attribute. Although, a user walks through a fence according to the conventional technologies, the present invention enables the fence to be set such that a user cannot pass through it by defining the user's viewpoint volume. Thus, a more realistic viewpoint movement can be realized.

For example, an attribute of "steps" can be defined as an interference restriction attribute, and an average slope angle can be defined and set so that a user goes smoothly up and down on them at a specified slope angle. Although a user could not go up or down the steps or has unrealistically walked up and down the steps, the present invention easily realizes a realistic walking up and down the steps.

Furthermore, a restriction at the time of an interference can be defined and set as a parameter function of a contact force, and the contact force (physical quantity of, for example, a collision force product) between objects associated with the interference is calculated so that an attribute of a "paper partition", which is not affected at a small contact force but is broken at a large contact force, can be defined.

As a result of an interference, not only a constraint condition on the movement of an interfering object associated with an interference but also the reaction movement with the interference as a trigger of an activate switch is defined and set as one of attributes. Thus, defined is an "object movable upon interference" as a type of attribute. For example, realized are an attribute of an "automatic door" to be moved by a switch of another object's interference and an attribute of a "variation" which starts a varying animation operation such as a free form deformation (FFD). Therefore, a realistic simulation world can be easily realized with a larger number of variations.

A reaction attribute assigned to an object can also be defined for a moment other than the time of an interference. For example, defined is an object reacting as being triggered by a switch at an external activate instruction, for example, a user's mouse click on a screen. Thus, an attribute of an "automatic door" to be started only by an interference can be easily extended to a door opened by a user's click depending on the definition of a switch. Therefore, a very realistic and fantastic walk-through simulation can be easily realized.

Furthermore, a sound as well as a movement can be set as a reaction attribute. The attribute defining/setting unit 33 defines a sound output attribute as a reaction attribute, and edits as to what kind of sound is used. The state change calculating unit 13 displays an image movable according to an activated reaction attribute, and activates the sound output unit 39 if a sound output attribute is specified, outputs the sound, and displays dynamic images.

Thus, an attribute of a "sound" is realized as a reaction with a switch, and can be defined as a kind of attribute in an increasing number of multimedia systems in recent simulation fields.

The attribute distribution display unit 37 displays a reaction attribute defined and set for an object and a switch activated by the attribute so as to practically indicate what is set in a world, for example, a virtual world in which a number of objects exist. Thus solved is the problem that a common user sets a switch for a wrong object or forgets as to which object an activation switch is assigned.

FIG. 5 shows an example of a virtual world for use in explaining the first embodiment. FIGS. 6 through 13 show examples of the information of objects forming the virtual world shown in FIG. 5.

In the first embodiment, the following typical attributes are used. The names and contents of the attributes are examples only and referred to for easier explanation. It is obvious that the present invention is not limited to these attributes but can simultaneously assign various attributes.

A wall, steps, a paper partition, and a floor are provided as interference attributes in the present example shown in FIG. 5.

The attribute of a wall refers to the feature of an object that the viewpoint cannot walk on the object having this attribute which permits nothing to pass through the object even if the object is sloping. When an object is defined in a virtual world, the default interference attribute is a "wall".

The attribute of "steps" has a parameter of an average slope angle calculated using real form of steps and the information about the lowest plane in the gravity direction.

	Document ID	U	Title	Current OR
147	US 4325910 A	☒	Automated multiple-purpose chemical-analysis apparatus	422/64
148	US 4300298 A	☒	Apparatus for the production and display of moving pictures	40/430
149	US 4227245 A	☒	Digital computer monitored system or process which is configured with the aid of an improved automatic programming system	700/95
150	US 4219874 A	☒	Data processing device for variable length multibyte data fields	712/300
151	US 4216528 A	☒	Digital computer implementation of a logic director or sequencer	700/95
152	US 4215407 A	☒	Combined file and directory system for a process control digital computer system	700/95
153	US 4215406 A	☒	Digital computer monitored and/or operated system or process which is structured for operation with an improved automatic programming process and system	700/95
154	US 4203154 A	☒	Electronic image processing system	345/26
155	US 4130880 A	☒	Data storage system for addressing data stored in adjacent word locations	711/201
156	US 4084259 A	☒	Apparatus for dot matrix recording	358/3.2
157	US 4065756 A	☒	Associative memory with neighboring recirculated paths offset by one bit	365/49
158	US 3992697 A	☒	Character recognition system utilizing feature extraction	382/203
159	US 3882463 A	☒	Character recognition apparatus	382/217
160	US 3872433 A	☒	OPTICAL CHARACTER RECOGNITION SYSTEM	382/175
161	US 3766532 A	☒	DATA PROCESSING SYSTEM HAVING TWO LEVELS OF PROGRAM CONTROL	712/247
162	US 3752288 A	☒	ELECTROGRAPHIC PRINTER WITH PLURAL OSCILLATING PRINT HEAD	400/322
163	US 3617134 A	☒	OPTICAL IMAGE FRAME COORDINATE DATA DETERMINING SYSTEM	356/141.3
164	US 3568155 A	☒	METHOD OF STORING AND RETRIEVING RECORDS	707/2

The information about the lowest plane indicates the information about a horizontal plane in contact with the floor among a lot of planes forming a staircase. For example, the information refers to a plane number of the lowest plane. The viewpoint can go up and down along the slope angle.

The attribute of a paper partition refers to the feature of an object that the viewpoint cannot walk on the object having this attribute even if the object is sloping. The attribute can be defined with a parameter indicating the pressure at which another object passes through the object. Another object is permitted to pass through the object of a paper partition only when another object clashes into the object with a pressure larger than a predetermined pressure.

The attribute of a "floor" refers to the feature of an object that the viewpoint can walk on the object having this attribute however steep or even vertical the object is. Variations of walks (for example, a walking at a constant height from the floor) can be realized by appropriately setting the viewpoint (height of the viewpoint or eyes).

The reaction attributes in the first embodiment indicate a reaction movement and sound, or indicate an activation switch. The reaction attributes indicating a movement refer to rotation, parallel movement, and sound.

The attribute of "rotation" refers to the feature of an object that the object automatically starts rotating as being triggered by a switch. Using this attribute, specified are a start/end position, the type of rotation such as a fixed direction, a reverse direction, etc. For example, needles of a clock, a door knob, a rotating door, an opening/closing of a book, a drawbridge, etc. can be realized using the attribute.

The attribute of "parallel movement" refers to the feature of an object that the object starts automatic parallel movement by being triggered by a switch. With this attribute, specified are a plane on which a movement is made, a start/end position of the movement, the type of movement such as one-way, two-way, etc. For example, the attribute can be used to realize a sliding door, a window, a a drawer, etc.

The attribute of a "sound" (sound output attribute) refers to the feature of an object that the object outputs a sound or a voice by being triggered by a switch according to sound data preliminarily stored in the object.

For example, a virtual world comprises the objects shown in FIG. 5. First, the objects are defined. Since the form, position, etc. of an object can be defined as in the prior art technologies, the detailed explanation about them is omitted here. Described below in detail is the data structure after the definition of the objects. According to the first embodiment, an attribute can be assigned to each object on an attribute edit screen.

The object information about steps 51 shown in FIG. 5 is managed as the data as shown in FIG. 6. The information refers to data of a common type and therefore common objects. The bounding volume refers to a size of a space including the object and is determined for easier cross over calculation. The position matrix refers to the position of the object in a three-dimensional space of the virtual world. The name refers to the identifier of the object. In this case, the name is "steps A". The interference attribute data are attribute information set by the attribute defining/setting unit 33 shown in FIG. 4. The attribute type is "steps". The data include a parameter of the average slope angle of 30° and the information about the lowest plane in the gravity direction (plane number of the lowest plane). The viewpoint can go up and down the steps at the slope angle. The texture data refer to the color, pattern (texture), etc. of the object. The color of the steps is defined as dark brown, and the texture is defined as the grain of wood. Additional data are the form data indicating the type of form (mesh), and coordinates, and physical data including the mass and the coordinates of the gravity. No reaction attribute is assigned to the steps 51.

The object information about handrail 52 shown in FIG. 5 is managed as the data as shown in FIG. 7. Since the contents of the common data are similar to those of the steps 51, described below is the attribute information about the present invention. The attribute type of the handrail 52 is defaulted at "wall". Therefore, the viewpoint cannot move on or pass through the handrail 52. No reaction attribute is assigned to the handrail 52.

The object information about window 53 shown in FIG. 5 is managed as the data shown in FIG. 8. The attribute type of the interference attribute of the window 53 is a "paper partition" with the maximum pressure of 25.0. It indicates the durable pressure, and the window 53 permits an object to pass through it only when it receives a clash force equal to or larger than the pressure of 25.0. No reaction attribute data are defined for the window 53.

The object information about a floor 54 shown in FIG. 5 is managed as, for example, the data shown in FIG. 9. The attribute type of the interference attribute of the floor 54 is "floor". Therefore, the viewpoint can walk on this object. No reaction attribute data are defined. The object information of a wall 55 shown in FIG. 5 is defined similarly. The interference attribute of the wall 55 is defaulted at "wall".

The object information about a door 56 shown in FIG. 5 is managed as, for example, the data shown in FIG. 10. The attribute type of the interference attribute of the door 56 is "wall". Furthermore, the door 56 is assigned a reaction attribute, and the type of the attribute is "reaction". Its animation type is "rotation" and a rotation start/end position matrix is defined. It has a door knob as a switch and starts its rotation by the click on a door knob 57.

The object information about the door knob 57 shown in FIG. 5 is managed as, for example, the data shown in FIG. 11. The attribute type of the interference attribute of the door knob 57 is "wall". "Switch" is defined as the attribute type of the interference attribute of the door knob 57. The switch type is "click". The "click" indicates a clicking operation of, for example, a mouse on a screen, and permits a reacting object to be operated. In this example, the reacting object is the door 56.

The object information about a box 58 shown in FIG. 5 is managed as, for example, the data shown in FIG. 12. The attribute type of the interference attribute of the box 58 is "wall" which prohibits the viewpoint from walking over. Two attributes of "reaction" are defined as reaction attributes. One is the animation type "rotation" and associated with the viewpoint as a switch. When the object comes in contact with the viewpoint as described later, it starts a predetermined rotation. The other attribute is the animation type "sound" and indicates a reaction of outputting a sound. A use sound data used when the sound is output are preliminarily stored in an area managed by the identification information "sound 31". It is switched by the viewpoint. When the object comes in contact with the viewpoint as described later, it outputs the predetermined sound data.

The object information about a viewpoint 59 shown in FIG. 5 is managed as, for example, the data as shown in FIG. 13. The data type of the viewpoint is "viewpoint". The viewpoint 59 indicates the position and direction of the eyes of a user who is supposed to walk in a virtual world. There are no physical data of the form, but the viewpoint is

	Document ID	U	Title	Current OR
1	JP 2000194719 A	☐	METHOD AND DEVICE FOR MANAGING DATA	
2	JP 2000133611 A	☒	IMPLANTATION MASK	
3	JP 11024039 A	☒	IMAGE EXPOSING DEVICE	
4	JP 10189745 A	☒	SEMICONDUCTOR INTEGRATED CIRCUIT LAYOUT DEVICE	
5	JP 09114639 A	☒	MASK DATA GENERATION CIRCUIT AND BIT FIELD OPERATION CIRCUIT	
6	JP 09050112 A	☒	PHASE SHIFT MASK	
7	JP 08317287 A	☒	X-RAY IMAGE PICKUP DEVICE	
8	JP 08129168 A	☒	PROJECTION TYPE IMAGE DISPLAY DEVICE	
9	JP 07040598 A	☒	PRINT OUTPUT METHOD AND ITS CONTROL DEVICE FOR SERIAL PRINTER	
10	JP 06347335 A	☒	PHASE DIFFERENCE MEASURING APPARATUS	
11	JP 06276483 A	☒	PICTURE SIGNAL CODING METHOD, CODER, DECODING METHOD AND DECODER	
12	JP 06083858 A	☒	VECTOR INSTRUCTION PROCESSOR	
13	JP 05312733 A	☒	X-RAY INSPECTION	
14	JP 05139790 A	☒	MASK FILM FOR ION EXCHANGE TREATMENT	
15	JP 05021321 A	☒	ALIGNMENT DEVICE OF EXPOSURE DEVICE	
16	JP 04288684 A	☒	COLOR SPACE CONVERSION METHOD	
17	JP 04074218 A	☒	ARITHMETIC CIRCUIT	
18	JP 03173474 A	☒	SEMICONDUCTOR DEVICE	
19	JP 03044734 A	☒	DATA SHAPING CIRCUIT	
20	JP 02230320 A	☒	DATA PROCESSOR	
21	JP 02054677 A	☒	DECODING METHOD FOR VARIABLE LENGTH CODE	
22	JP 02046084 A	☒	IMAGE PICK-UP DEVICE	

processed in the same manner as a common object for standardization. The viewpoint volume defining unit 34 defines the volume of the viewpoint for the viewpoint 59 as in the definition of the bounding volume of a common object. The volume of the virtual viewpoint is determined as, for example, an ellipsoid or a sphere, according to the bounding volume of the viewpoint. In FIG. 5, the viewpoint 59 has an elliptic viewpoint volume. FIG. 13 shows a special case of an elliptic viewpoint having a bounding volume of a sphere with 7.5 in radius. Any other forms can be optionally specified as a viewpoint volume. The attribute of "switch" is defined as a reaction attribute to the viewpoint 59, and the switch type is "contact". The reacting object is the above defined "box". It indicates that when the viewpoint 59 comes in contact with the box 58, a process is activated according to the reaction attribute defined for the box 58.

The attribute defining/setting unit 33 shown in FIG. 4 defines and sets an attribute when a virtual world is edited or simulated. FIG. 14 shows the structure of the attribute setting menu processed by the attribute defining/setting unit 33. The "display of an attribute" or the "setting of an attribute" can be selected from the initial menu. In an "attribute display" menu, either "interference attribute display" or "reaction attribute display" can be selected.

FIG. 15 shows an example of a display of an interference attribute after being selected from the "interference attribute display" menu. If the "interference attribute display" menu is selected, an interference attribute of each object in the object information shown in FIGS. 6 through 13 is referred to. As shown in FIG. 15, for example, the name of an object and an interference attribute name already set are displayed in the virtual world. Thus, a user is informed of the set interference attribute.

Clicking a mouse at the displayed attribute on a screen opens a small window as shown in FIG. 16 for more detailed parameters. FIG. 16 shows a window displayed when the mouse is clicked at the attribute of the steps.

FIG. 17 shows an example of the display of reaction attributes displayed when the "reaction attribute display" menu is selected. When the "reaction attribute display" menu is selected, the reaction attributes of each object in the object information shown in FIGS. 6 through 13 are referred to. For example, as shown in FIG. 17, the reaction attributes set for each object are represented in respective colors. Otherwise, the distribution of the reaction attributes can be represented by letters "switch", "rotating object", etc. as in the example of the display of interference attributes. In this example, an object having the attribute of a switch is represented in pink, an object having the reaction attribute in pale blue, and the other objects in white depending on the type of reaction attribute. Thus, all objects assigned a reaction attribute are represented in respective colors. Then, clicking an optional switch, for example, the "door knob" displays the reaction attribute object group ("door" in this example) switched by the "door knob" in an emphasized manner. That is, for example, pink is emphasized into red, pale blue is emphasized into blue, and so forth.

If the "interference attribute" setting menu is selected in the attribute setting menu as shown in FIG. 14, then displayed is the menu listing the interference attributes which can be set for a object to be set. For example, if a step attribute is selected, then the window shown in FIG. 16 which is referred to in association with the example of the display of interference attributes is displayed. In the window, an average slope angle is automatically calculated and displayed according to the predetermined form data of an object. The angle can be modified by dragging the mark indicating the default value of the average slope angle. The setting can be deleted using the cancellation button (CANCEL). The termination button (END) terminates the setting of an attribute.

FIGS. 18A, 18B, and 18C show examples of setting screens. If the "reaction attribute (switch)" setting menu is selected in the attribute setting menu shown in FIG. 14, a reaction attribute setting screen is displayed. On this screen, "click switch" and "contact switch" can be selected. The "click switch" indicates that a switch type reacts with an external activate instruction, while the "contact switch" indicates that a switch type reacts when the object comes in contact with another object in the virtual world. If the "contact switch" is selected, for example, a window shown in FIG. 18A is displayed. Adding, deleting, entering, and editing a reacting object in the list is performed by clicking the button after selecting a corresponding item in the list.

There are two methods of opening a window for use in setting the movement of an actual reacting object as shown in FIGS. 18B and 18C. One is to click the button at a corresponding object in the reacting objects to be activated. The other is to directly select on a screen a reacting object to be edited and to select a reaction attribute in the menu.

FIG. 18B shows an example of the display of a window when the "rotating object" menu is selected in setting a reaction attribute. The rotation angle, the type of rotation, etc. can be set in the window. Likewise, the movement start/end position and the type of movement can be set for "displacing object" using a similar screen.

FIG. 18C shows an example of the display of a window when the "sound output object" menu is selected. The list of a file storing an acoustic performance time, a sound source, and sound data called "mididata" can be optionally set.

Described below is the process performed by the state change calculating unit 13 shown in FIG. 4 by referring to FIG. 19. Process steps S1 through S19 in the following explanation correspond to steps S1 through S19 shown in FIG. 19.

S1: A display instruction is issued to the result display unit 38 to display the initial screen or the image of a calculation result on the display device 40.

S2: If there are sound data to be output, then the sound data is output through the sound output unit 39.

S3: Present time t is set to t' by adding a predetermined time value Δt ($t'=t+\Delta t$).

S4: On the screen displaying a virtual world, it is determined whether or not the button has been clicked at an object, that is, whether or not an activate instruction has been issued from the activate instruction input unit 35. If no, control is passed to step S7.

S5: If the button has been clicked at an object, the reaction attribute of the clicked object is checked to determine whether or not its switch attribute is defined. If no, the process in the next step S6 is omitted.

S6: If the switch attribute is defined, then searched and activated is a reacting object triggered by the clicked object.

S7: Next, it is determined whether or not there is an object moving in the virtual world. If no, control is returned to step S1. An object moving in FIG. 5 is an object which has been already activated among the viewpoint 59, the door 56, and the box 58.

S8: If there are objects moving in the virtual world, one (hereinafter referred to as obselected and temps

	Document ID	U	Title	Current OR
23	JP 02046078 A	☒	IMAGE PICK-UP DEVICE	
24	JP 01259397 A	☒	COLOR LIQUID CRYSTAL DISPLAY	
25	JP 01223565 A	☒	INFORMATION PROCESSOR	
26	JP 01223564 A	☒	INFORMATION PROCESSOR	
27	JP 01223563 A	☒	INFORMATION PROCESSOR	
28	JP 01012215 A	☒	SOLAR SENSOR	
29	JP 63151948 A	☒	EXPOSING MASK	
30	JP 62061324 A	☒	STAGE NOISE DETECTION OF ELECTRON BEAM EXPOSURE DEVICE	
31	JP 60070836 A	☒	TRANSMITTER	
32	JP 59146008 A	☒	FOCUSING DETECTOR	
33	NB8910197	☒	RMU Mask Generation From Shift Amount or Pad/Start/End Specifications	
34	NN8706172	☒	Increasing Memory Reliability Through Address Translation and Per Page Bit Swapping	
35	NN79055027	☒	Bit Matrix Transposition Algorithm., May 1979.	
36	NN78023598	☒	Mask Controlled Byte Handling. February 1978.	
37	US 200400057444 A	☒	Amorphous substrate crystallization apparatus for transistor fabrication, has convergence/divergence element and phase shift mask to produce light beam having periodical intensity distribution with inverse peak portion	
38	US 6618804 B	☒	Centrifuge circuit in digital computer, has swap stages which forward received mask bits and data units in reverse order, if mask bit received from specific mask bit positions are set and clear respectively	
39	US 200300098970 A	☒	Lens aberration monitor for optical lithography system, has phase shifting element arranged on mask to form ring-shaped pattern on substrate, for detecting lens aberration	
40	US 200201698088 A	☒	Bit reordering method in computer for cryptography involves centrifuging data element as function of masks that are created with reference to destination descriptor representing a reordering pattern of data element	
41	US 6408275 B	☒	Compressing and decompressing audio data by masking lower order bits of digital audio samples and shifting in higher order bits from adjacent sample	
42	FR 2805361 A	☒	Method of acquisition of rounding parameters in floating-point multiply accumulate, uses shifting of mantissa bits for easy fusion of incoming value with accumulated value	
43	JP 2000352810 A	☒	Phase shift mask for manufacture of semiconductor device, has shading element mounted in corner area at upper portion of shading band area arranged to enclose corner areas of circuit pattern	
44	CA 2275821 A	☒	Compression method for audio data in voice communication systems, by masking predetermined number of lower order bits from each sample of stream of digital audio samples	

selected and temporarily updated at present time. A temporary update indicates a process in which the position of object A at time t' is temporarily calculated on the assumption that object A does not interfere with another object. If it actually does not interfere with another object, the result is validated.

S9: It is checked whether or not any other object has its data type of "common type" (not a viewpoint, a light source, etc. but an object having a certain form). If yes, the interference (contact/clash or collision) between the object (hereinafter referred to as object B) and object A is determined.

S10: Unless there is object B interfering with object A, then control is returned to step S7 and to the process of the next moving object. If there is object B interfering with object A, the following process is performed.

S11: Calculated is the movement amount at interference, that is, the contact pressure at the clash between objects A and B. It is calculated based on the mass, etc. defined as object information and a given movement speed.

S12: It is determined whether or not object A is a viewpoint. If yes, control is passed to step S14. If no, the process of step S13 is performed.

S13: Unless object A is a viewpoint, the type of the interference attribute of object B is checked and the following movement interference calculation is performed depending on the interference attribute of object B.

If the attribute of object B is "wall", then the common object (object A) clashes with the wall (object B). Since object B prohibits other objects from passing through it, the temporary update of the movement of object A is canceled.

If the attribute of object B is "steps", a step attribute is processed as a wall attribute in principle because object A is not a viewpoint. Therefore, the temporary update of the movement of object A is canceled. However, a size of a common object can be regarded as a volume of a viewpoint so that the common object as well as the viewpoint can go up and down the steps.

If the attribute of object B is "floor", the temporary update of the movement of object A is canceled because the floor works on a common object as having a wall attribute. However, the size of the common object can be regarded as the volume of a viewpoint so that the common object as well as the viewpoint can move on the floor.

If the attribute of object B is "paper partition", then the contact pressure calculated in the process in step S11 is compared with the parameter (maximum pressure) of the interference attribute (paper partition) of object B. If the contact pressure is larger, the temporary update of the movement of object A is determined as an actual position. If the contact pressure is smaller, the temporary update is canceled.

S14: If object A is a viewpoint, it is determined whether or not the viewpoint is assigned a viewpoint volume. If yes, control is passed to step S15. If no, control is passed to step S16.

S15: If object A is a viewpoint and a viewpoint volume is assigned to the viewpoint, then the type of interference attribute of object B is checked and the following movement interference calculation is performed depending on the interference attribute of object B.

If the attribute of object B is "wall", then object B prohibits other objects from passing through it, and the temporary update of the movement of object A (viewpoint) is canceled.

If the attribute of object B is "steps", then object A (viewpoint) can go up and down the steps. Accordingly, the temporary update of object A is canceled, and the position of the viewpoint is calculated such that the height of the viewpoint volume can be maintained at a constant level in the direction of the gravity of the virtual world. The calculation is performed according to the parameter of the interference attribute (steps) of object B and the information about the lowest plane (plane number). The calculation result is determined as an actual position.

If the attribute of object B is "floor", then object A (viewpoint) moves on the floor. Therefore, the temporary update of object A is canceled, and the position of the viewpoint is calculated such that the height of the viewpoint volume can be maintained at a constant level in the direction of the gravity of the virtual world. The calculation is performed using the form of object B, and the result is determined as an actual position.

If the attribute of object B is "paper partition", then the contact pressure calculated in the process in step S11 is compared with the parameter (maximum pressure) of the interference attribute (paper partition) of object B. If the contact pressure is larger than the maximum pressure, the temporary update of object A is determined as an actual position. If it is smaller, then the temporary update is canceled.

S16: If object A is a viewpoint and a viewpoint volume is not assigned to the viewpoint, then the type of the interference attribute of object B is checked and the following movement interference calculation is performed depending on the interference attribute of object B.

If the attribute of object B is "wall", then object B prohibits other objects from passing through it, and the temporary update of the movement of object A (viewpoint) is canceled.

If the attribute of object B is "steps", since no viewpoint volume is defined for object A (viewpoint), then, the attribute of steps of object B works on object A as if it were an attribute of a wall, and the temporary update of the movement of object A is canceled.

If the attribute of object B is "floor", since no viewpoint volume is defined for object A (viewpoint), then, the attribute of a floor works on object A as if it were an attribute of a wall, and the temporary update of the movement of object A is canceled.

If the attribute of object B is "paper partition", then the contact pressure calculated in the process in step S11 is compared with the parameter (maximum pressure) of the interference attribute (paper partition) of object B. If the contact pressure is larger than the maximum pressure, the temporary update of object A is determined as an actual position. If it is smaller, then the temporary update is canceled.

S17: After the results of the movement interference calculations performed in the processes of the above described steps S13, S15, and S16 have been stored in a notification area for the result display unit **38**, the reaction attribute of object A is checked and it is determined whether or not a switch attribute of a contact switch is set. If no, control is returned to step S7.

S18: If a switch attribute of a contact switch is assigned to object A, then it is determined whether or not a reacting object is object B and whether or not the reaction attribute (reaction) of object B is associated with object A as a switch. If object B is a reacting object

	Document ID	U	Title	Current OR
45	US 6144986 A	☒	Data set sorting network for use in parallel processor environment, includes control mask which is shuffled whenever redundant shuffling operation is performed on data elements	
46	JP 09114639 A	☒	Bit field operation circuit with mask data generating circuit - has shifter which responds to 2-bit shifter control signal and shifts 16-bits of 32-bit mask bits and outputs as mask data	
47	EP 573712 B	☒	Prodn. of wavelength converter element - comprises forming stripe mask on lithium, tantalate C-plate, exchanging lithium ions with protons in non-masked portions	
48	DE 4141024 A	☒	Conversion of colour image signals - using 32-bit microprocessor employing shift and masking operations	
49	RD 305052 A	☒	Parity generation logic for rotate-merge unit - uses rotator output predictor to generate parity whilst rotate-merge unit is operating	
50	DE 3686307 G	☒	Binary image rotation method for digital image processor - exchanged selected group of bits stored in register with second group of bits stored in second register	
51	SU 1167613 A	☒	Microprogram computer multiplex channel - has microprogram memory at inputs of exchange status former, mask register and data switching unit taken to data registers	
52	SU 1117632 A	☒	Data shift circuit for array element ordering - has four ordering code formers each with NOT=gate and four multiplexers, and eight adders at inputs of switches	
53	EP 90137 A	☒	Access control system for data transfer of variable length records - between central processing units and direct access stores, updating buffer address register as writing progresses	
54	SU 864340 B	☒	High output computer data shift unit - has mask generator outputs connected to high and low order bits of output register	
55	US 4065756 A	☐	Associative charge coupled memory - has neighbouring recirculated memory paths offset by one bit and has large number of word locations	

and is switched by object A, then the process of the next step S19 is performed. Otherwise, control is returned to step S7.

S19: Object B is activated and added to a group of the moving objects as one of them. Then, control is returned to step S7 and the process is repeated on the next moving object.

Next, the process in step S15 shown in FIG. 19 is explained in detail by referring to FIGS. 20 through 25, where object A is a viewpoint assigned a viewpoint volume.

FIG. 20 is the flowchart showing the movement interference calculation in which the attribute of object B is "wall". In FIG. 20, the state change calculating unit 13 determines whether or not the interference pressure of object A is larger than the maximum pressure of object B (step S21). If yes, the temporary update of the movement of object A is validated and the position of object A is updated (step S23). If it is smaller than the maximum pressure of object B, then the temporary update of the movement of object A is canceled (step S22). In this case, the position of object A is not updated.

FIG. 21 is the flowchart of the movement interference calculation performed when the attribute of object B is "steps". FIG. 22 shows the position of object A amended as a result of the calculation.

In FIG. 21, the state change calculating unit 13 obtains the intersection between the center line in the gravity direction of the bounding volume of temporarily updated object A and the lowest plane of object B, that is, the intersection P1 between the vertical line from the center of object A to the lowest plane of object B and the lowest plane of object B (step S31). Obtained next is the amended point P2 on an average slope line according to the intersection P1 and an average slope angle of object B (step S32). Then, the position of object A is amended such that the lowest point of the bounding volume of object A matches the amended point P2, and then object A is moved (step S33).

Thus, as shown in FIG. 22, the bounding volume of the temporarily updated object A is moved onto the average slope line of object B.

FIG. 23 is a flowchart of the movement interference calculation performed when the attribute of object B is "floor". FIG. 24 shows a position of object A amended as a result of the calculation.

In FIG. 23, the state change calculating unit 13 obtains the distance L1 between the center of the bounding volume of the temporarily updated object A and object B (step S41). Obtained next is the depth L2 of the bounding volume of object A sinking into object B by subtracting L1 from the radius of the bounding volume of object A. L2 is added to the height of the center of the bounding volume of object A to obtain an amended point of the center (step S42). Then, the position of object A is amended such that the bounding volume of object A comes in contact with object B, and object A is moved (step S43).

Thus, as shown in FIG. 24, the bounding volume of the temporarily updated object A is moved onto object B.

FIG. 25 is the flowchart of the process performed in the movement interference calculation if the attribute of object B is "paper partition". In FIG. 25, the state change calculating unit 13 determines whether or not the interference pressure of object A is larger than the maximum pressure of object B (step S51).

If yes, the temporary update of the movement of object A is validated and the position of object A is updated (step S52). Next, it is determined whether or not there is a reaction movement as a result of which object B is broken (step S53). If yes, then the reaction movement of object B is activated (step S54). If no, the process terminates.

If the interference pressure of object A is smaller than the maximum pressure, then the temporary update of the movement of object A is canceled (step S55), and the processes of and after step S53 are performed. At this time, the position of object A is not updated.

To obtain an exact movement interference, an interference calculation should be performed between all intersecting planes of object A with object B, and the contact force at each intersection is calculated to obtain the direction of the movement of object A and the distance of the movement. In this method, a large amount of calculation is required to determine for each plane the intersection and the contact force. Furthermore, to realize the state after a contact, a precise physics calculation should be performed using a contact force and a friction force.

On the other hand, according to the first embodiment, it is not necessary to determine an intersection for all planes of object A. Furthermore, the amount of movement is used to determine the state after a contact, and reaction information is stored for each attribute, thereby eliminating a precise and complex physics calculation. As a result, the large amount of calculation in the precise movement interference calculation can be considerably reduced.

The above explanation of the processes refers to the typical attributes. If a new attribute is defined, then a process routine can be entered depending on its attribute. Similarly, the calculation can be easily performed depending on the attribute. The movement interference calculation for the new attribute can be optionally set. Various methods, for example, a method of generating a subroutine, a method using a branch table, etc. can be used depending on the system of a CG simulation.

As described above, the first embodiment introduces a concept of an attribute, and defines and sets the attribute for an object in a virtual world in a walk-through simulation. Then, the movement interference calculation of the object is performed at a high speed and the conventional problem that the object undesirably sinks into another object can be successfully solved. Thus, the movement of the viewpoint of a user can be performed easily and realistically.

FIG. 26 shows the configuration of the second embodiment of the present invention.

The second embodiment is a CG data display system for generating and displaying image frames which change one after the other as time passes. The system comprises a calculating unit 61 for calculating CG data to be displayed, a display unit 62 for displaying a calculation result performed by the calculating unit 61, a predicting unit 14 for predicting the time at which a calculated frame is displayed, and a time control unit 15 for controlling the calculating unit 61 and the display unit 62 based on the prediction output by the predicting unit 14, and controlling time relating to the display of dynamic images.

The time control unit 15 controls the calculation of the n-th frame performed by the calculating unit 61 and the display of the (n−1)th frame on the display unit 62 such that these processes are concurrently performed. It changes the interval of the display of frames according to the prediction output by the predicting unit 14.

The time control unit 15 predicts the frame display time using the predicting unit 14 before actual calculation to set time of a world to be displayed through computer graphics corresponding to the logically described actual time. Setting the time of the displayed world corresponding to the actual time means that an image generated through CG data